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Magnetic Forces for Intrusion of Buccal Segments in Dolichofacial Individuals with Anterior Open Bite : A Report of Six Cases

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Abstract

MAGNETIC FORCES FOR INTRUSION OF BUCCAL SEGMENTS IN DOLICHOFACIAL INDIVIDUALS WITH ANTERIOR OPEN BITE

by

Rosa Maria I. Reimann-Blaseio

The correction of anterior open bite in dolichofacial individuals with magnetic forces has been studied. The attempt was made to intrude buccal segments by using interarch magnets set in repulsion in order to correct the anterior open bite of six dolichofacial patients. It was expected to intrude the posterior sections with these magnetic forces, to autorotate the mandible and to close the anterior open bite by decreasing the lower facial height and rotating the facial axis closed. The magnets were placed in each arch only on those teeth that needed intrusion, mainly second premolars and existing molars, for a period of 21 weeks on six patients with a vertical pattern and an anterior open bite. It was found that in this period of magnetic wear there was little or no intrusion of the buccal segments. There were no appreciable changes in the position of the facial axis. Three cases showed slight reduction of the anterior open bite independently of the magnetic forces. There was a problem with production of posterior crossbites which possibly were instrumental in reducing the intrusion capabilities of the magnetic forces. It was concluded that forces exerted by the magnets were great enough to result in tooth intrusion but design changes in the magnetic appliance were necessary to improve buccal section intrusion.

Key Words: Magnetic, Intermaxillary, Posterior Intrusion, Dolichofacial, Open Bite, Mandibular Autorotation.

LOMA LINDA UNIVERSITY

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Each person whose signature appears below certifies that this manuscript in his opinion is adequate, in scope and quality, in lieu of a thesis for the degree Master of Science.

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LIST OF FIGURES AND PHOTOGRAPHS

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INTRODUCTION

Anterior open bite in patients with hyper-divergent facial patterns are challenging orthodontic cases. Treatment of these patients often requires complex mechanotherapies which open the facial axis and require greater patient cooperation. Often, the results achieved are less than ideal. Non-growing Dolichofacial patients with anterior open bite typically require maxilofacial surgery to correct the malocclusion. However these patients are often treated with orthodontic appliances due to financial obstacles or personal objection to surgery. It would be ideal to find a non-surgical solution which would benefit a high-angle case by reducing the lower facial height via mandibular autorotation.

Recent literature presents the use of magnetic forces to induce orthodontic tooth movement.[7, 8, 9, 11, 16, 18, 22] With the advent of high forces produced by magnets composed of the rare earth-cobalt elements, orthodontic movement with relatively small magnets.[7, 8, 9, 16, 18, 22, 25.]have become feasible.

It is postulated that magnets placed in repulsion between upper and lower arches cause intrusion of posterior teeth[7, 8, 11], resulting in a reduction of lower face height and anterior bite closure.

This paper presents six cases treated with repulsion interarch Samarium-Cobalt magnets in an attempt to reduce the lower facial height via posterior tooth intrusion and mandibular autorotation.

LITERATURE REVIEW

The prosthodontic literature provides several reports of magnets used in denture stabilization and retention. Only recently have articles appeared in the literature reporting on magnetic forces in orthodontics[7,8,9,11,16,18,22]

In the late 1960's, the development of permanent magnet alloys composed of cobalt and rare earth elements was announced by J. J. Becker.[5] These new magnetic alloys are highly superior to the popular Platinum-Cobalt (PtCo) and Aluminium-Nickel-Cobalt (Alnico) magnet alloys. The best known alloy of this type is Samarium-Cobalt ($SmCo_5$),which has an extremely high magnetic permanence or hardness.

"Hardness" or "softness" of magnetic materials is described by the term "intrinsic coercivity." Soft magnetic materials can be magnetized by weak magnetic fields but loose their magnetic properties once the field is removed. Their magnetism is easily reversed which allows for their use in transformers. Very high magnetic fields are required to create a good permanent magnet, such as $SmCo_5$. Yet these magnets remain strongly magnetized even when the field is removed. The coercivity of $SmCo_5$ is five times that of PtCo and more than 10 times that of the best Alnico alloys. Because of this extremely high coercivity $SmCo_5$ magnets can be made very small (2 mm or less) and not loose their high magnetic field strength. It is this property which permits their use in orthodontics and other areas of dentistry.

In 1972 Strnat [21] reviewed the magnetic properties of the new rare earth-transition metal alloys. The term "rare earths" refers to the elements with atomic numbers between 57 (lanthanum) and 71 (lutetium) and to yttrium (39). These elements are quite abundant in the earth's crust in spite of the misleading name. They are based on intermetallic phases of the type RCo_5 where R stands for one of the several light rare earth elements. The formula

$SmCo_5$ received much attention due to the early belief that only this formula could yield a high energy product (a term used to describe the power of the magnetic material). Strnat also reported on work done in preparing excellent sintered magnets from other combinations of rare earths with cobalt. In the future, the magnets of interest will be a combination of rare earths, iron, and cobalt with the formula of $R_2(Co,Fe)_{17}$.

The effect of magnetic fields on living tissues has been investigated extensively since the late 19th century. These were reviewed by R. O. Becker[6] in 1963, Aceto et. al.[1] in 1970, and E. H. Frei [14] in 1972. The reported biological effects varied with the type of field applied and duration of application.

Unusual findings were reported by Barnothy [2,3] in the late 1950's and throughout the 1960's. With high magnetic field exposure to mice, he found (1) a reduction in the number of circulating polymorphonuclear cells, (2) growth arrest and death of adult mice during 10 day exposure in magnetic fields of 4,500 Gauss (G), (3) inhibition of the oestrus cycle in female mice, (4) slowing of normal aging process, (5) abnormal zona fasciculata of the adrenal gland, bone marrow, liver, and spleen, and (6) morphological and physiological transformations in mammalian cells.

Blechman and Smiley [7], discussed the bioeffects of magnetic devices on humans and animals. They cited studies at Tufts University School of Mededicine where animals were exposed to fields with a gradient product of 10^8 G/cm^2 and showed no toxic effect, as well as studies at Columbia University, College of Physicians and Surgeons that reported no toxic or histopathologic effects on rats exposed for a period of one month to permanent fields ranging from 200 to 1,200 G. They also mentioned that at Columbia University another study was conducted where electromagnetic fields were successfully used to enhance the calcification process in bone fractures without deleterious side effects. In other fields of medicine, magnets permanently implanted in humans caused no adverse effects.[4,12,15,17] Blechman and Smiley [7] determined that the magnitude of electromotive forces induced by a magnetic orthodontic appliance was much less than the resting potential of red blood cells passing through vessels near the appliance. They concluded that it is unlikely that any appreciable physiological effect could be caused by the magnetic field production and that permanent magnets were biologically safe.

In 1981 Esformes[13] and coworkers studied the biological effects of magnetic fields generated with $SmCo_5$ magnets. They utilized in-vitro and in-vivo experimental models. They examined tissue cultures of several representative human and animal cell lines and showed no obvious effects on cell growth rate, morphology, or the ability to grow and remain confluent. They reported no deleterious effects of the magnetic field on an in-vivo study of wound and bone healing in rats.

In 1979 Tsutsui *et. al.*[25] reported on the use of $SmCo_5$ magnets in dentistry. They reported that the magnets were highly corrosion resistant and innocuous to tissues. They concluded that: 1) $SmCo_5$ magnets are superior in magnetic properties to other kinds of magnets. 2) The strong magnetic forces in small magnets allow dental applications. 3) The magnetic properties of $SmCo_5$ magnets are stable below 200^o C and the forces do not decay with time. 4) Corrosion resistance (for artificial saliva solutions of 0.1% Na_2S and 1% NaCl) is good. 5) $SmCo_5$ is a harmless alloy. 6) The magnet is brittle and should be handled with care.

Toto and coworkers[23, 24] found that Pt-Co magnets implanted in 10 dog mandibles were well accepted by osseus and fibrous tissues. They found no difference between magnetized and non-magnetized alloys of Pt-Co. The Pt-Co implants did not cause adverse tissue reactions.

An article by Cerny[10] in 1980 reported on the reaction of dental tissues to magnetic fields. He noted the conflicting results of tissue reaction in the literature and studied the tissue reaction in young adult female dogs. Cerny implanted $SmCo_5$ discs at the marginal gingival level in cuspids. Histologic examination of the pulp, buccal mucosa , periodontal brackets becomes smaller. Two reports on cuspid retraction were discussed. A girl age 11.0 and a boy age 11.8 had attracting magnets placed for cuspid retraction. The investigators found fast and steady canine retraction resulting in shorter treatment time. Unlike conventional appliances that experience the loss of force with time, the magnetic brackets maintained their force in attracting or repelling modes . The magnetic force was reported to be inversely proportional to the square of the distance. They concluded that magnets may allow more physiological tooth movement without clinical discomfort.

Another study using magnets for orthodontic tooth movement was done by Muller[18] in 1984. She bonded small $SmCo_5$ magnets onto the labial surface of upper centrals to close diastemas ranging between 0.7 mm to 1.9 mm of 7 patients, ages 8 yrs 11 mos to 12yrs $1^1/_2$ mos. In all but one case the diastema closed in a time span of 2 days to 2 weeks. She reported rotation, uprighting, and in some cases even root paralleling with only slight sensitivity of the teeth. The reason one case showed no diastema closure is because the magnets came off several times. Muller's clinical observations suggested that more complicated tooth movements such as rotating, uprighting, and bodily movement could be produced by magnets.

In 1985 Blechman[8] published an article in which he described the use of $SmCo_5$ magnets in place of intermaxillary and intramaxillary mechanics. He observed good three-plane vector control independent of patient cooperation in two patients. He theorized that class II mechanics, posterior intrusion or extrusion, crossbite correction, or any combination of these, is possible with $SmCo_5$ magnets. A 13-yr old Hispanic boy with class I molar relationship and anterior crowding underwent four first premolar extractions and magnetic orthodontic treatment in conjuction with edgewise appliance therapy. No elastic cooperation was necessary. The total active treatment time was approximately 1 yr. Cephalograms before and after treatment showed that the maxilla and mandible developed in their normal growth pattern. The correction of the malocclusion was evident from intraoral photographs. Another 13 yr-old caucasian boy with a history of allergy, mouth breathing, tongue thrusting, thumb-sucking, and nail biting was treated with magnets. He had a class I molar relationship on the right side and a class II tendency on the left. A class II canine relationship, an 8 mm overjet, an anterior open bite, a crossbite on the left side, and a mandibular midline shift to the left was evident. The maxillary left central incisor was treated endodontically due to earlier traumatization. The treatment began with rapid palatal expansion prior to magnet therapy. The expansion subsequently relapsed. Active magnetic force was then applied for 1 yr to achieve maxillary expansion, crossbite and cuspid class II correction, elimination of overjet, midline correction, and closure of anterior open bite. The cephalograms before and after the period of magnetic treatment showed a decrease in maxillary dental protrusion. A slight increase in the cant of the occlusal plane occurred, which was attributed to an inhibition of the vertical eruption of the upper posterior teeth. Some of the conclusions were: 1) only magnetic forces were used and elastics were not necessary; 2) cooperation problems associated with elastics can be eliminated; 3) no adverse side effects were noted and there was good toleration of the magnets; 4) the necessary vector control for the correction of the reported malocclusions was attained.

In 1986 Dellinger[11] reported on three cases treated with the Active Vertical Corrector. The appliance consisted of repelling $SmCo_5$ magnets embedded in an acrylic bite block to achieve intrusion of maxillary and mandibular posterior teeth, resulting in autorotation of the mandible and correction of anterior open bite. The force generated by the appliance was 700 gms per magnetic unit with a 0 mm air gap. In the first case the anterior open bite was corrected in 4 $^1/_2$ months on a boy age 8 years and 11 months. The cephalometric tracings showed autorotation of the mandible with intrusion of the posterior teeth and extrusion of the anterior teeth. The second patient was a 13 year-old girl who wore the appliance for 7 months and closed the anterior open bite by posterior intrusion. There was greater premolar intrusion than necessary which the author attributed to placing the magnets too far anteriorly. Rapid palatal expansion was used after AVC appliance wear with relapse of the anterior open bite. A new AVC appliance was worn for 2 months. In this case the author claimed redirection of growth during appliance wear showing horizontal growth with little vertical growth. The third case was a 10 year 10 month old girl with a significant anterior open bite which was markedly improved after 4 months of appliance use. The cephalometric tracings showed mandibular counterclockwise rotation. The author found that appliance wear 12 hours per day provided patients with acceptable results. He claimed that the appliance had been successful in both adults and children. Young individuals experienced more rapid correction than the skeletally mature adult. Dellinger concluded that posterior intrusion was possible with the AVC appliance and that the rate of tooth movement was considerably greater than that of conventional approaches, such as high-pull headgear, bionator, activator, or conventional bite block therapy.

MATERIALS AND METHODS

Six anterior open bite dolichofacial patients were selected from the Orthodontic Clinic at Loma Linda University School of Dentistry. Five of them had already been in treatment for several years demonstrating poor cooperation with elastic wear to reduce the anterior open bite. The sixth patient was starting treatment at the time of this study. All patients had hyper-divergent facial patterns and an anterior open bite ranging from 1 to 6mm between the incisal edges.

Bands were fitted on all teeth that needed intrusion, impressions were taken, and poured up taking care that the bands remained in their correct positions within the alginate impression while pouring. A wax bite in centric occlusion was carefully taken while the patient was standing.

Models and wax bites were sent to the laboratory of Medical Magnetics Inc. where the magnets were attached to the bands in correct orientation for tooth intrusion (OrthoMag® Magnetic Force arrangement).

Cephalometric records, models, and photographs were taken before magnet placement. The magnetic bands were cemented (Photographs 1 & 2 showing corect alignment of magnetic modules at cementation) with Ketac-cement for durability and greater bond strength[24]. The patients were instructed to avoid hard foods as much as possible, and to wear a chin strap at night and during the time they were at home (15 hrs / day). They were also advised to be aware of keeping their teeth together as much as possible for greater effect of the magnetic forces.

The patients were checked at intervals of two to four weeks for magnet adjustment taking care to direct the forces for intrusion and avoid crossbite forces (Fig. A & B). Progress photographs were also taken.

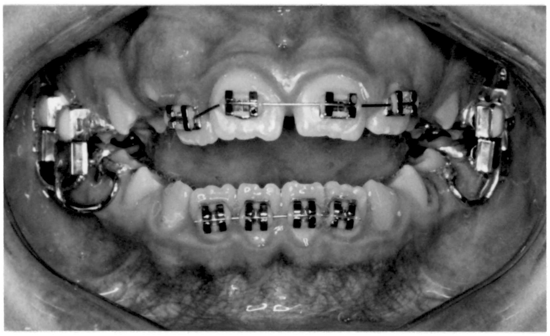
The magnetic appliances were constructed of 2 mm x 5 mm x 4 mm $SmCo_5$ magnets jacketed in stainless steel cases. The magnets were also coated with a biocompatible polymer coating for added resistance of the magnet to damage and to provide additional barriers to leaching of corrosion products into the oral cavity. To hold the magnets securely in their stainless steel casings they were further covered with a biocompatible adhesive.

For adjustability, the magnetic modules on the mandibular teeth are attached to the band by 0.036" round wires of elgiloy metal (Fig. C) of approximately 1 cm in length. The magnets on the maxillary teeth are soldered to the bands directly and have acrylic buttons on the buccal surfaces to protect the inner surface of the cheeks from irritation. The alignment between the maxillary and mandibular magnetic modules is obtained by bending the wires in the mandibular arch with care to avoid damaging the magnets.

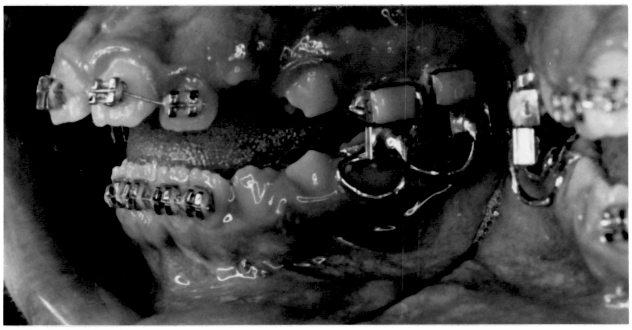
The magnetic surfaces facing each other between the upper and lower arches are set in repulsion and are exposed (except for the biocompatible coatings) for maximum force action when the magnets are in centric contact.

No arch wires connecting the teeth to be intruded were used in order to allow each individual tooth to take the path of least resistance while intruding. At the end of a 21 or 22 week period the magnets were removed and final cephalometric records, models and photographs were taken for evaluation of treatment.

Treatment was evaluated for each patient cephalometrically with beginning (T_A) and ending (T_B) lateral tracings and Ricketts' four-point superimpositions in order to show treatment results more accuratetely. Facial axis changes were determined by superimposing along the Na-Ba Plane at Center of Cranium. Maxillary skeletal changes were shown by superimposing along the Na-Ba Plane at Na. Dental changes within both upper and lower arches were evaluated by superimposing on the internal structures of each jaw; maxillary changes by superimposing on the ANS-PNS Plane at ANS, and the mandibular changes by superimposing on Corpus Axis at PM. Beginning and ending models were evaluated and measured to quantify results of constriction and expansion of both upper and lower arches. Photographs of interest were included as part of the case descriptions.



Photograph 1. Magnetic bands at cementation showing correctalignment and approximation



Photograph 2. Correct alignment and approximation of magnetic modules at cementation; lateral view.

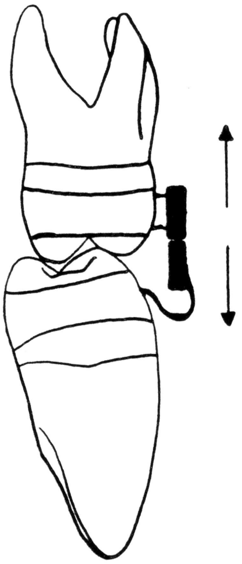


Fig. A. Magnetic modules aligned so that the direction of forces exert pure intrusion

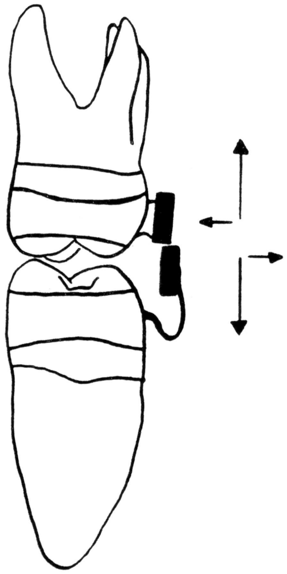


Fig. B. Magnetic modules have become malaligned so that extraneous lateral forces are present

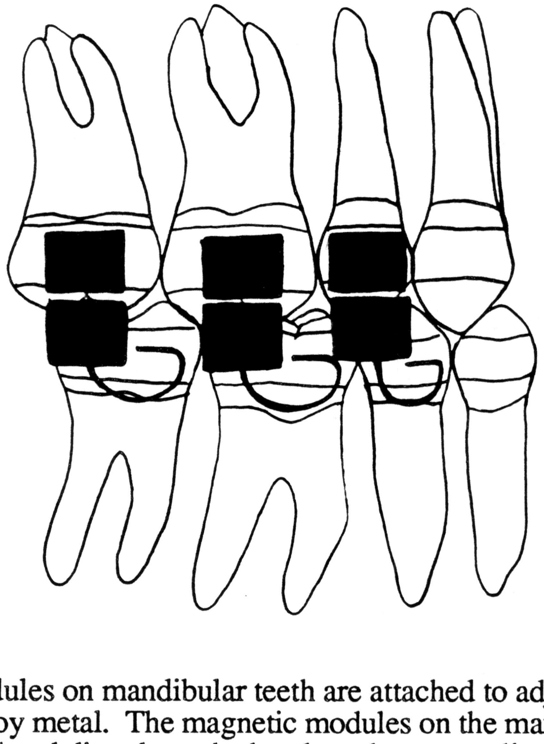


Fig. C Magnetic modules on mandibular teeth are attached to adjustable 0.036" round wires of elgiloy metal. The magnetic modules on the maxillary teeth are soldered directly to the bands and are not adjustable.

CASE #1 (K. S.)

SUMMARY DESCRIPTION

A 16 year old male had been in treatment since December 1983. Prior to magnet placement the patient had an anterior open bite of 1 mm which was being treated with anterior up and down elastics. Patient cooperation was poor. Cephalometric evaluation at T_A (Fig. 1A) showed this patient to be dolichofacial with a class I malocclusion (class II tendency) with four first premolars removed. The skeletal position of the maxilla and the mandible were normal with protrusion of both the upper and lower dentures. There was moderate mentalis strain and the two arches contacted only at the first and second molars.

TREATMENT PROCEDURE

Bands were removed from all molars and premolars. Photographs, x-rays, and impressions were taken immediately before placing magnets for buccal section intrusion (Photographs 1 and 2 show the correct alignment of the magnetic modules at time of cementation T_A). The patient was instructed to minimize eating of hard foods to avoid distortion of the magnets and to wear a chin strap at night and any other time possible to keep the magnets in closest proximity and maximum force. At approximately two week intervals the magnets were checked and adjusted where necessary for close approximation.

Two weeks after magnet placement the premolars showed some mobility from the magnetic force and development of a lingual crossbite of the maxillary molars was noted. After one and a half months of magnet wear, a crossbite appeared in which the upper first molars constricted while the lower first molars expanded. Measurements were taken to establish the amount of constriction and expansion. In the upper arch, the second premolar and the second molar widths remained stable. The first molars showed constriction of

3 mm. In the lower arch the expansion at the premolars and second molars was negligible, whereas the first molars had expanded 1.5 mm. The magnetic bands were removed from the maxillary first molars and a quadhelix appliance was constructed for expansion of the arch. The quadhelix was cemented with activation for expansion and intraoral photographs were taken (Photograph 3). An appointment was set for one week and crossbite correction was noted. At subsequent appointments magnets were approximated and the quadhelix was adjusted for expansion and buccal root torque as needed. Three months after magnet placement cross elastics were initiated to constrict the mandibular molars. There was poor elastic cooperation from the patient and three weeks after that, a lingual arch with constriction to the first molars was cemented (Photograph 4). All magnets were removed after 21 weeks of wear, and records taken (Fig. 1B).

TREATMENT RESULTS

Cranial Base Superimposition (Fig. 1C). Superimposing along the basion-nasion plane at center of cranium revealed a slight closing of the facial axis of 0.5°. The first molar came down the facial axis with slight more forward movement.

Maxillary Displacement (Fig. 1D). Superimposing along the basion-nasion plane at nasion indicated no change in A point position with slight rotation of the palatal plane showing a drop of PNS while the ANS point remained fairly constant.

Maxillary Superimposition (Fig. 1E). Superimposing on the ANS-PNS plane at ANS revealed no change at the premolar with very slight intrusion of the second molar and slight extrusion of the first molar. The greatest change is seen at the incisor which has been retracted.

Mandibular Superimposition (Fig. 1F). Superimposing on corpus axis at PM revealed slight intrusion of both first and second molars as well as slight intrusion of the premolar.

The incisor shows slight extrusion and retraction. Also the buccal section has moved forward.

In summary, patient #1 showed no appreciable change in facial axis or depression of the buccal segments. Mandibular molars expanded while maxillary molars constricted at the beginning of treatment. After quadhelix cementation, the upper molars and premolars expanded so that the final photographs and models show an overall expansion of both lower and upper arches. The lower premolars constricted as a result of the relative magnet alignment change to the upper premolars after quadhelix placement. The upper and lower incisors retracted due to flattening of the sectional arch wires and slight expansion between the cuspids in both arches.

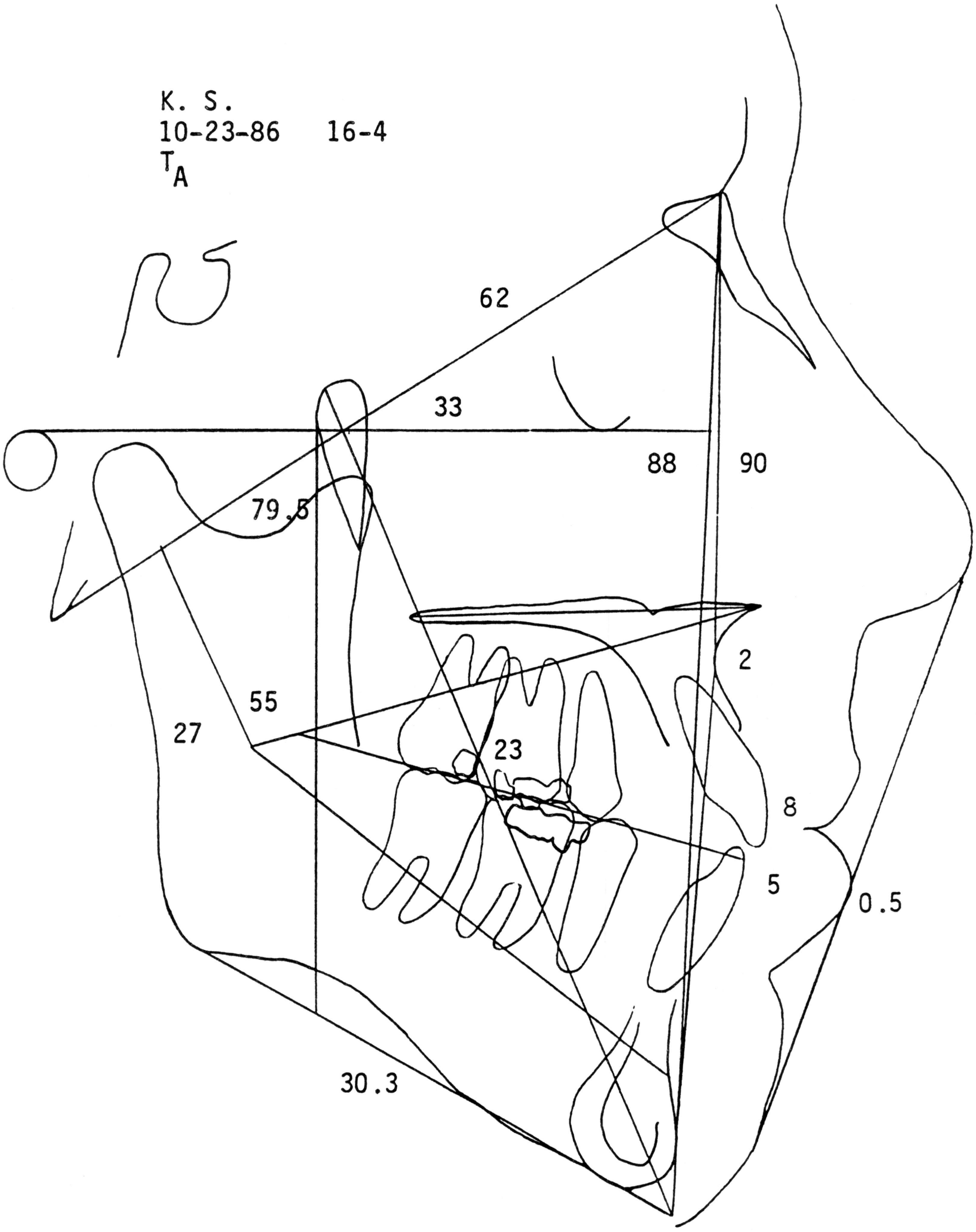


Fig. 1A

Cephalometric tracing (T_A) immediately before magnet placement.

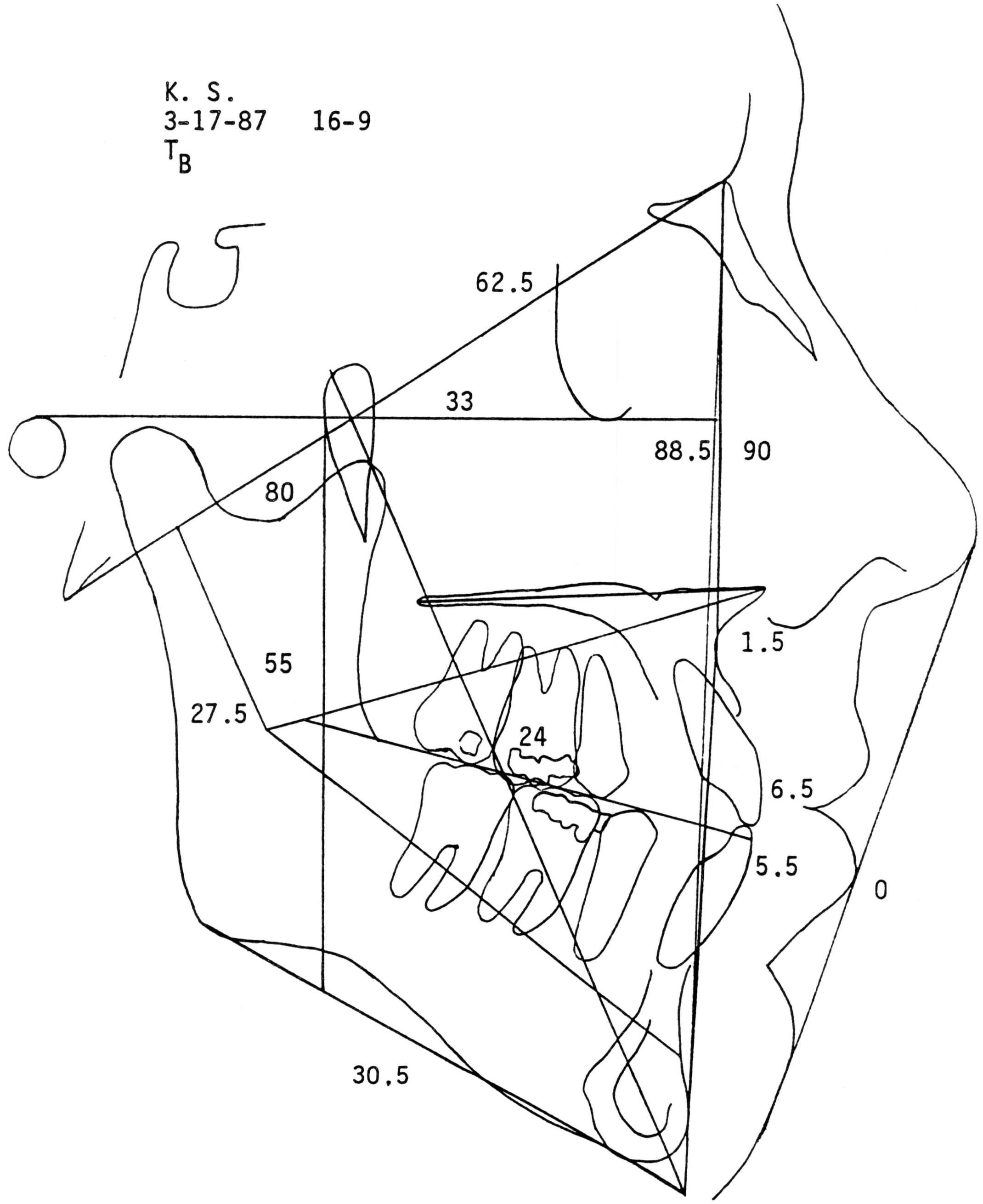


Fig. 1B

Cephalometric tracing (T_B) immediately following magnet removal.

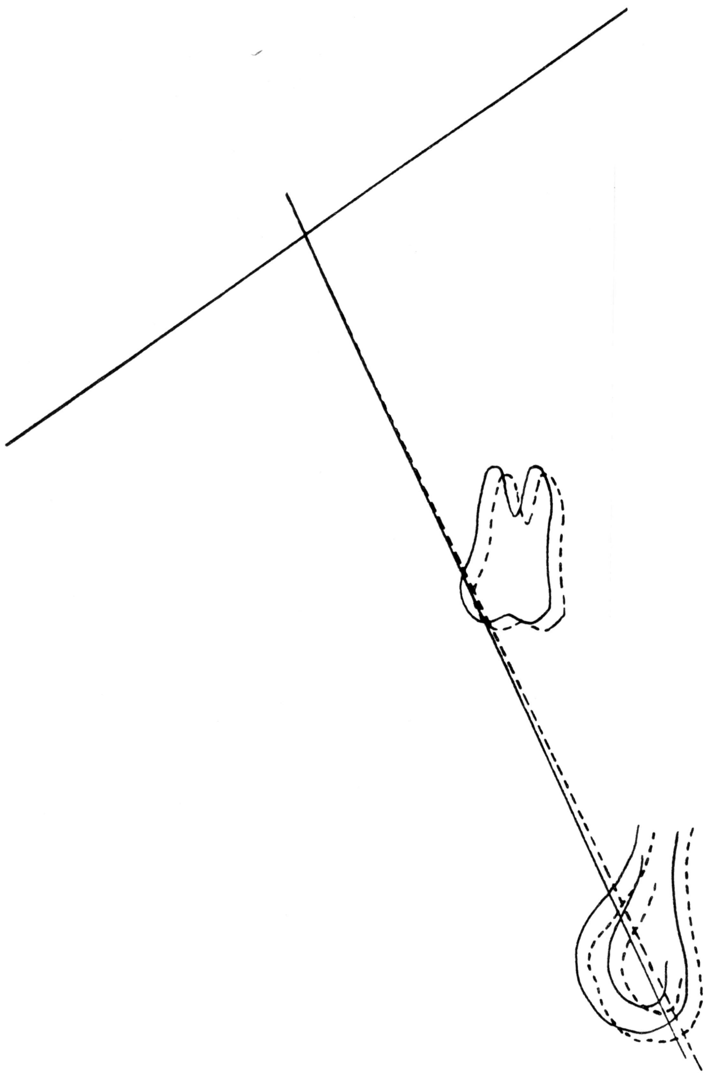


Fig. 1C

Cranial Base Superimposition along Ba-Na Plane at CC.
(T_A solid line; T_B dashed line).
Time interval between T_A and T_B for case #1 was 21 weeks.

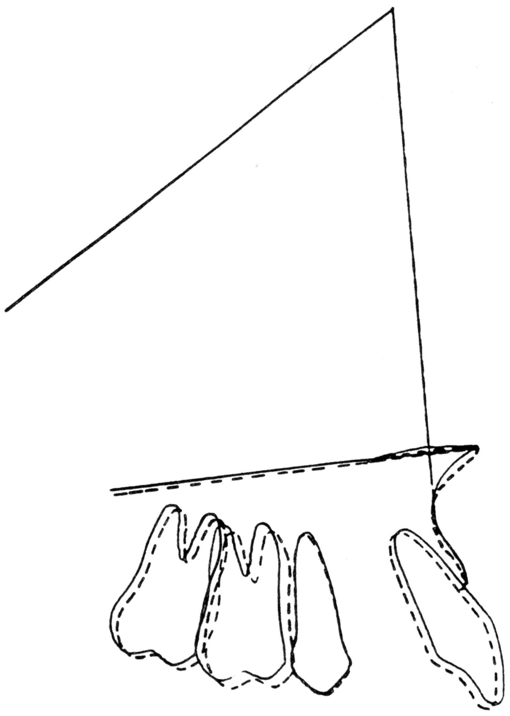


Fig. 1D Maxillary Displacement
Ba-Na Plane at Na.

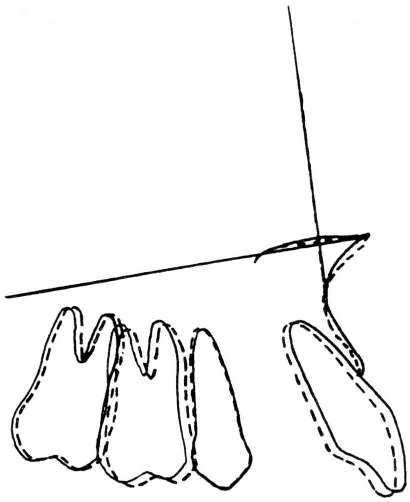


Fig. 1E Maxillary Superimposition
ANS-PNS at ANS.

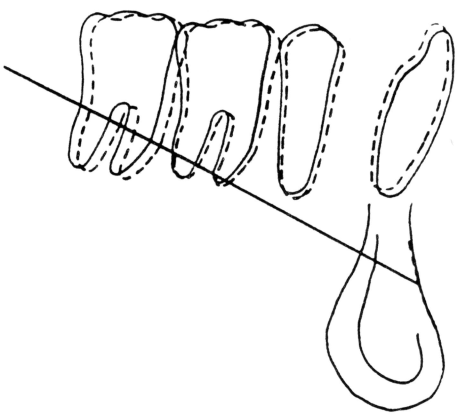
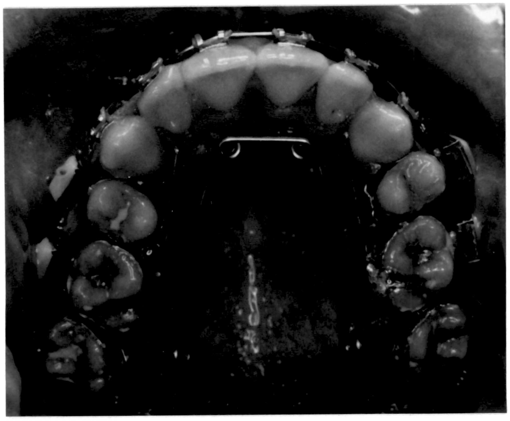
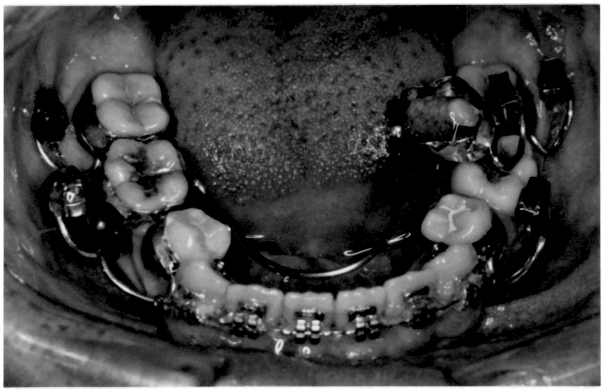


Fig. 1F Mandibular Superimposition
Corpus Axis at PM.



Photograph 3. Quadhelix in place for expansion after constriction in upper first molar region by extraneous magnetic forces.



Photograph 4. Lingual arch placed for constriction of the lower first molars to help correct upper lingual crossbite

CASE #2 (M. S.)

SUMMARY DESCRIPTION

M. S. began orthodontic treatment in February 1983. At age 14 he presented with missing maxillary laterals and permanent maxillary cuspids that were retarded in eruption. The malocclusion showed an end on class II div. 1 Angle classification. Cephalometric evaluation revealed a mesiofacial pattern with normal skeletal positioning of the jaws. Treatment was begun with reverse headgear to bring the upper dentition forward into a full class II molar relation. Cooperation was poor and class III elastics replaced the reverse headgear nine months later. Various kinds of class III elastics were continued for the next three years and the facial axis was opened several degrees. Progress records were taken, and the decision was made to continue treatment with magnets for posterior intrusion in an attempt to close the facial axis again. Cephalometric evaluation in October 1986 (Fig 2A.) showed this patient to be Dolichofacial (the mandible had rotated clockwise during previous treatment). There was moderate mentalis strain and an anterior open bite of 1.5mm. The Angle classification was still end on class II.

TREATMENT PROCEDURE

Bands were removed from all molars and second premolars. Photographs, x-rays, and impressions were taken immediately before placing magnets for buccal section intrusion. The patient was instructed in proper care of the magnetic appliance as described for patient #1. Magnets were checked and adjusted for approximation with a three prong plier to avoid loosening the cemented bands. Reverse headgear was reinstated to advance the maxillary anterior section (hooked to the first premolars) for better interdigitation capabilities as the bite closed. Headgear cooperation was poor, and elastics were worn from the mandibular centrals to the maxillary first premolars instead. Eleven weeks after magnet placement a button was bonded to the lingual surface of the maxillary left first premolar for crossbite correction with elastic forces. Elastic cooperation was also poor. The following week, the mandibular left first molar magnet dislodged from its casing. The adhesive coating on the magnet which holds it securely within its steel casing had been damaged. The magnet was replaced into its stainless steel casing with ligature wire and acrylic and the band recemented. The magnetic appliance was removed after 21 weeks on March 25, 1987. Records were taken immediately following magnet removal (Fig. 2B).

TREATMENT RESULTS

Cranial Base Superimposition (Fig. 2C). Superimposing along the basion-nasion plane at center of cranium reveals no change in the facial axis and very slight movement of the maxillary molar forward.

Maxillary Displacement (Fig. 2D). Superimposing along the basion-nasion plane at nasion indicated no change in point A position or palatal plane. The molars show no intrusion while the premolar shows slight extrusion. Most of the change is at the central incisor which detorqued and extruded slightly.

Maxillary Superimposition (Fig. 2E). Superimposing on the ANS-PNS plane at ANS reveals the same dental change as described for figure 2D.

Mandibular Superimposition (Fig. 2F). Superimposing on corpus axis at PM reveals no intrusion of the first molar and second premolar. There is slight extrusion of the second molar and one can see an increase in torque of the central incisor.

In summary, patient #2 showed no appreciable change in facial axis position or posterior tooth intrusion. There was a 1.5 mm constriction at the upper first molars and second premolars, as well as a 2 mm expansion of the lower first and second molars as measured on the models. The upper incisors retracted due to interproximal space closure with gray chains on a sectional arch wire.

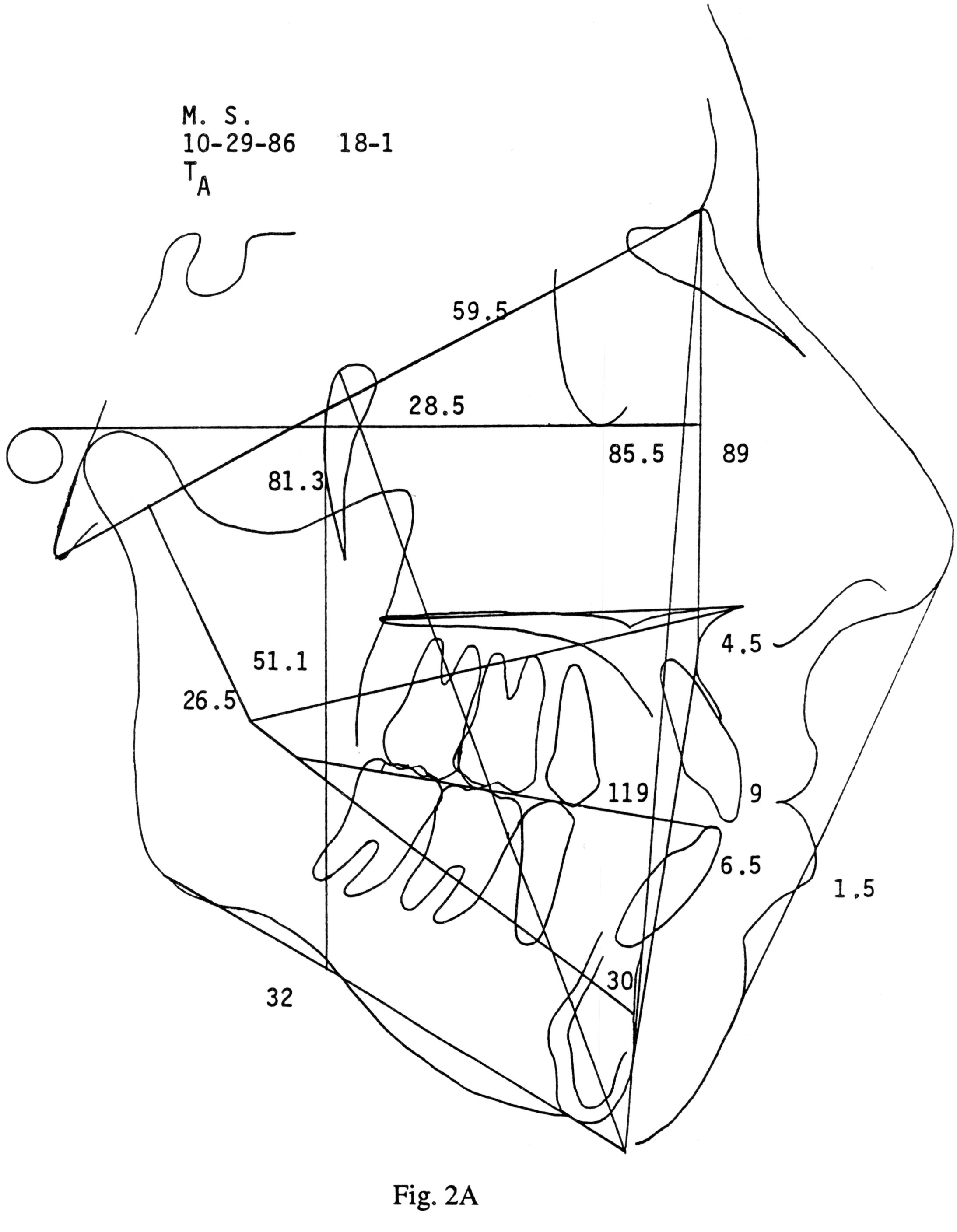


Fig. 2A

Cephalometric tracing (T_A) immediately before magnet placement.

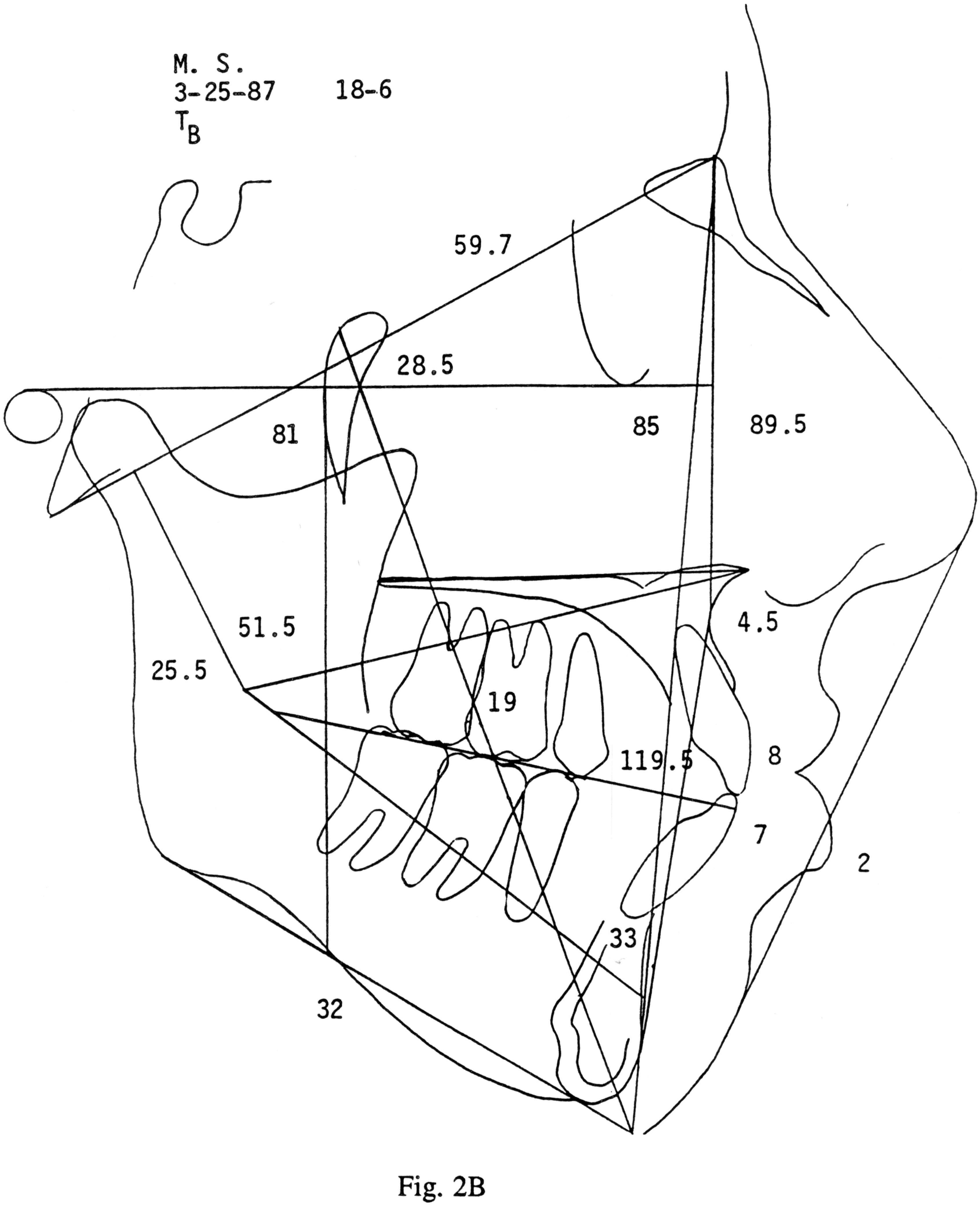


Fig. 2B

Cephalometric tracing (T_B) immediately following magnet removal.

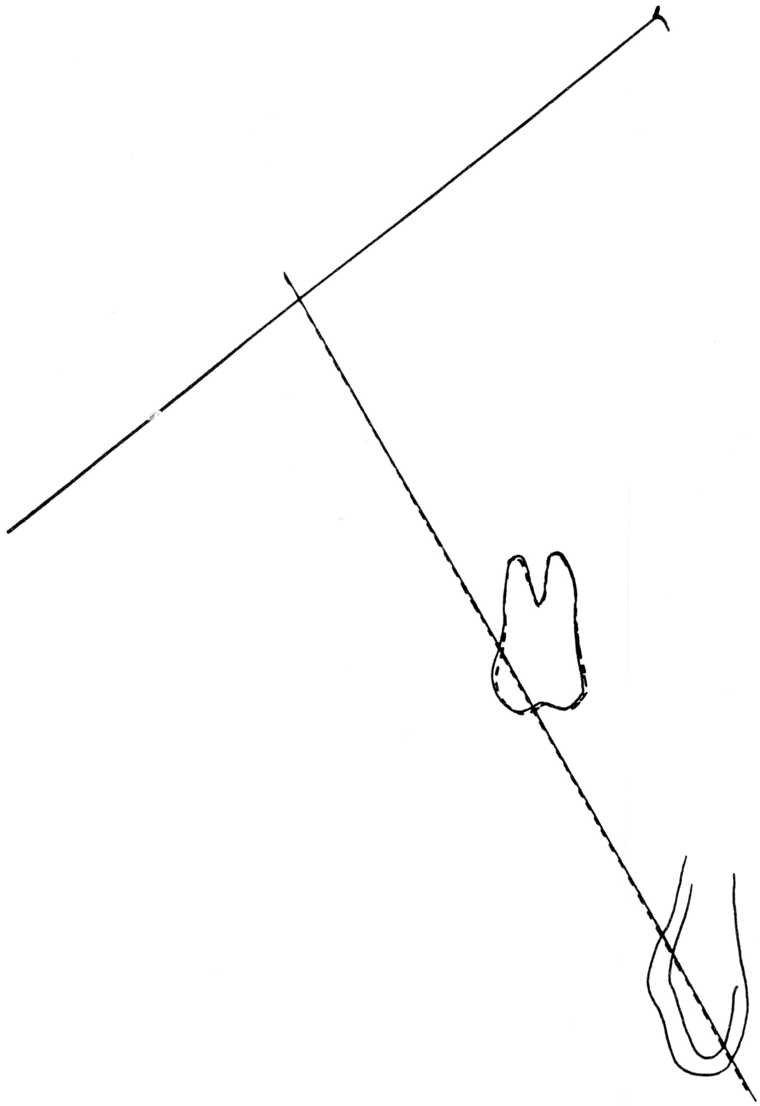


Fig. 2C

Cranial Base Superimposition along Ba-Na Plane at CC.
(T_A solid line; T_B dashed line).
Time interval between T_A and T_B for case #1 was 21 weeks.

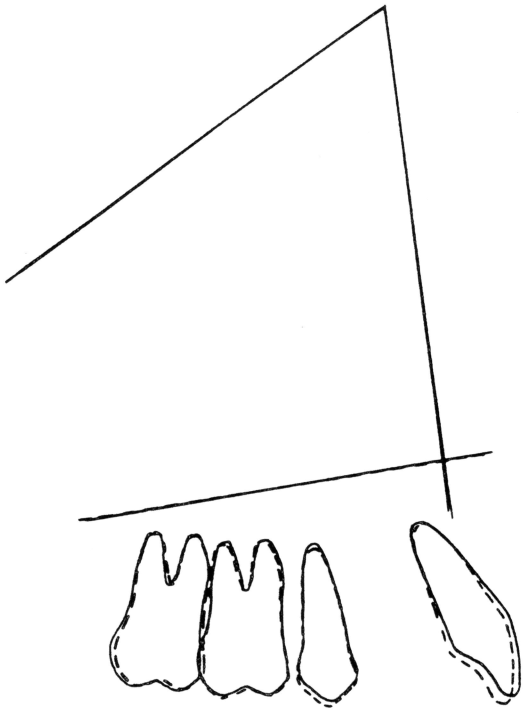


Fig. 2D Maxillary Displacement
Ba-Na Plane at Na.

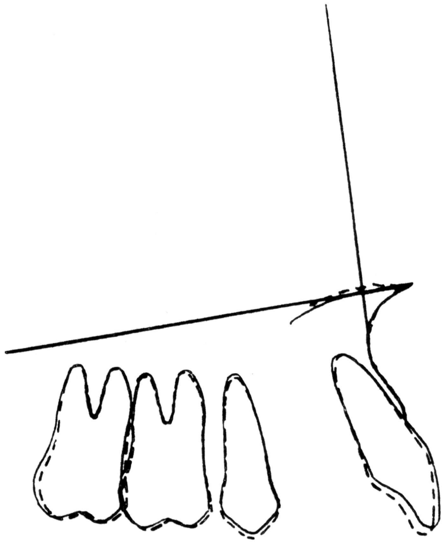


Fig. 2E Maxillary Superimposition
ANS-PNS at ANS.

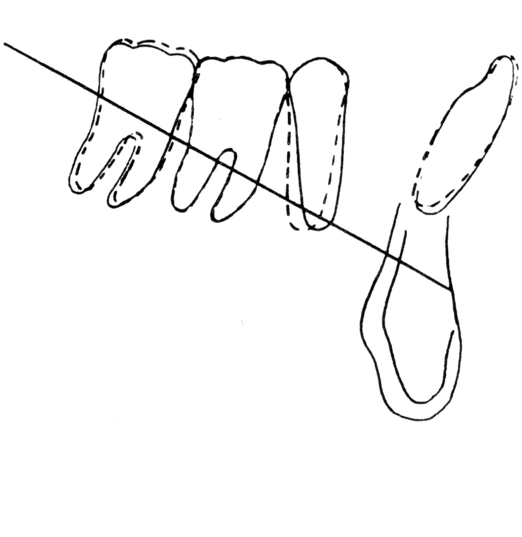


Fig. 2F Mandibular Superimposition
Corpus Axis at PM.

CASE #3 (D. A.)

SUMMARY DESCRIPTION

D. A. presented in 1983 with a mesiofacial pattern, class I molar relation and end on class II cuspid relation. All first premolars had been extracted. ALD in the mandibular arch was -2mm and in the maxillary arch the second premolars were severely rotated to the mesial. Over bite was 50% and there was a deep Curve of Spee. Class II elastics were begun and poor cooperation was noted in the progress records. Saif-springs were inserted two years after treatment was started and continued for 2 $^1/_2$ months when elastics were reinstated, again with poor cooperation. At the time of magnet placement the cephalometric evaluation (Fig. 3A) revealed a moderate dolichofacial pattern (the facial axis had been opened 7.5^o with orthodontic treatment). The maxillary and mandibular dentitions were protrusive. There was mild mentalis strain and an anterior open bite of 0.5mm.

TREATMENT PROCEDURE

Progress records were taken immediately before placement of magnets on Nov 6, 1986. Instructions for oral hygiene were given and also how to take care of the magnetic appliance. Lingual crossbite tendency was noticed at magnet placement on the left upper first molar and magnets were adjusted for crossbite correction at this time. Five weeks into magnetic treatment the crossbite was correcting on the left side while the maxillary first molar had developed a lingual crossbite. The lower magnets were difficult to adjust since they were contacting the lower bands and it was impossible to position them directly under the magnetic modules of the upper molars (Photograph 5). The magnetic bands were removed to construct a quadhelix for expansion of the maxillary molars and recemented the same day. One week later the crossbite was improving and corrected in four weeks after quadhelix placement. The magnets were being deflected a considerable amount (anywhere from 2 to 6 mm) between appointments possibly from eating hard food. It was stressed to the patient that a soft diet was indicated. The appliance was removed after 21 weeks of magnetic treatment and records were taken immediately following removal (Fig. 3B).

Treatment Results

Cranial Base Superimposition (Fig. 3C). Superimposing along the basion-nasion plane at center of cranium revealed a slight closing of the facial axis of 0.5°. The first molar was intruded and distalized slightly.

Maxillary Displacement (Fig. 3D). Superimposing along the basion-nasion plane at nasion indicated minimal change in point A position and minimal palatal rotation.

Maxillary Superimposition (Fig. 3E). Superimposing on the ANS-PNS plane at ANS revealed intrusion of both first and second molars as well as some intrusion and increased torque of the central incisor. The greatest intrusion is seen at the first molar while the second molar seemed to distalize more.

Mandibular Superimposition (Fig. 3F). Superimposing on corpus axis at PM revealed slight intrusion of the second molar. The first molar shows very slight extrusion while the incisor indicated slight extrusion and uprighting.

In summary, patient #3 showed slight closing of the facial axis with some intrusion of the maxillary molars especially the upper first molar. The force of intrusion must have been directed in such a way that there was also distal tipping of the maxillary molar crowns as seen in the cephalometric superimpositions. There was no appreciable intrusion or extrusion of the mandibular molars. From the models, 6 mm expansion was measured at the upper first molars and 3 mm at the upper second molars and second premolars due to the quadhelix appliance. The maxillary second molars tipped distally and buccally. In the lower arch there was a 2 mm constriction of the lower second molars due to the buccal tipping of the upper second molar which caused the magnetic modules to align in such a way to produce a constricting force on the lower second molar and expansion (buccal tipping) of the upper second molar. The mandibular first molars expanded 1 $^1/_2$ mm while there was no change of the width of the second premolars. Both upper and lower premolars had no magnets attached to them.

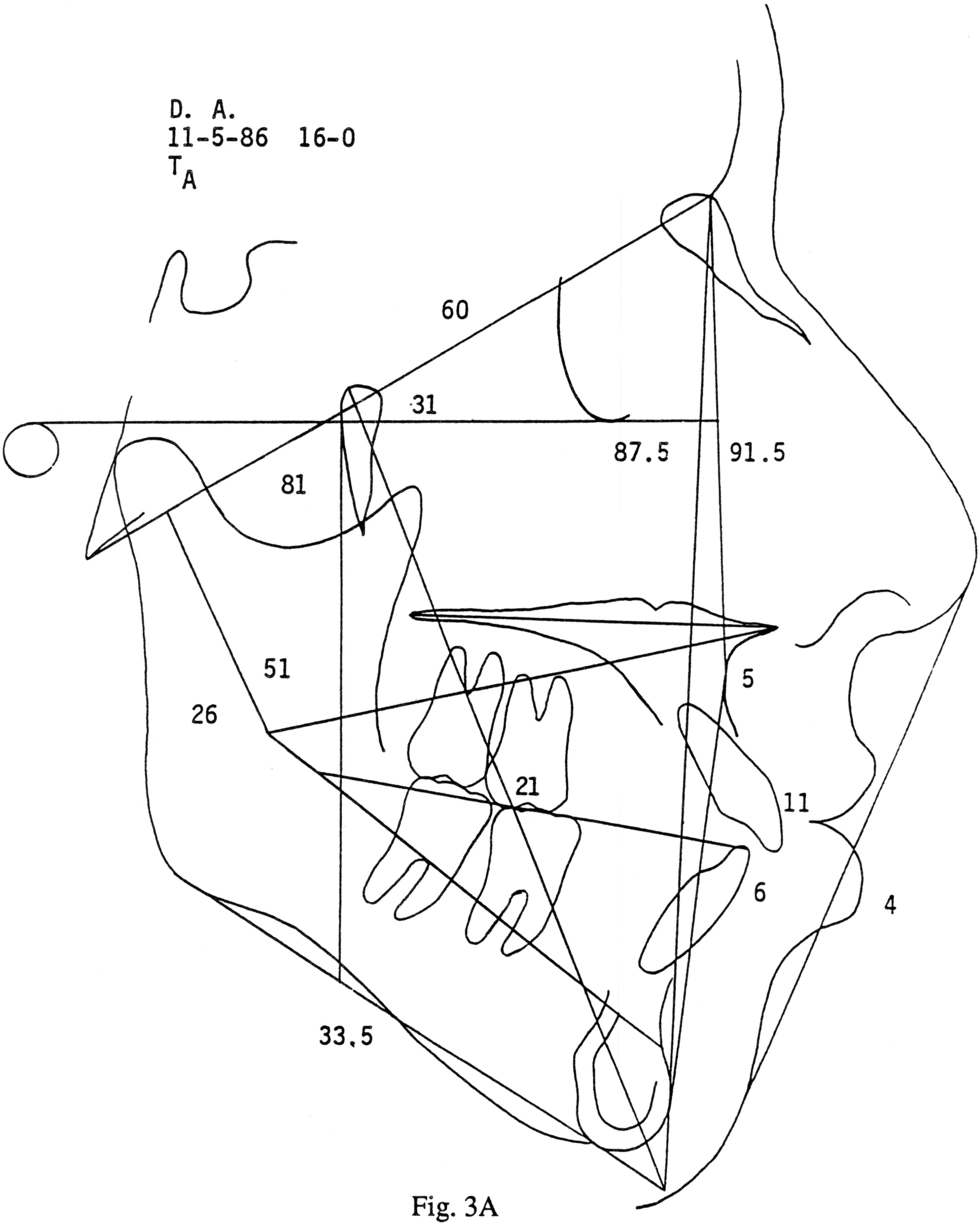


Fig. 3A

Cephalometric tracing (T_A) immediately before magnet placement.

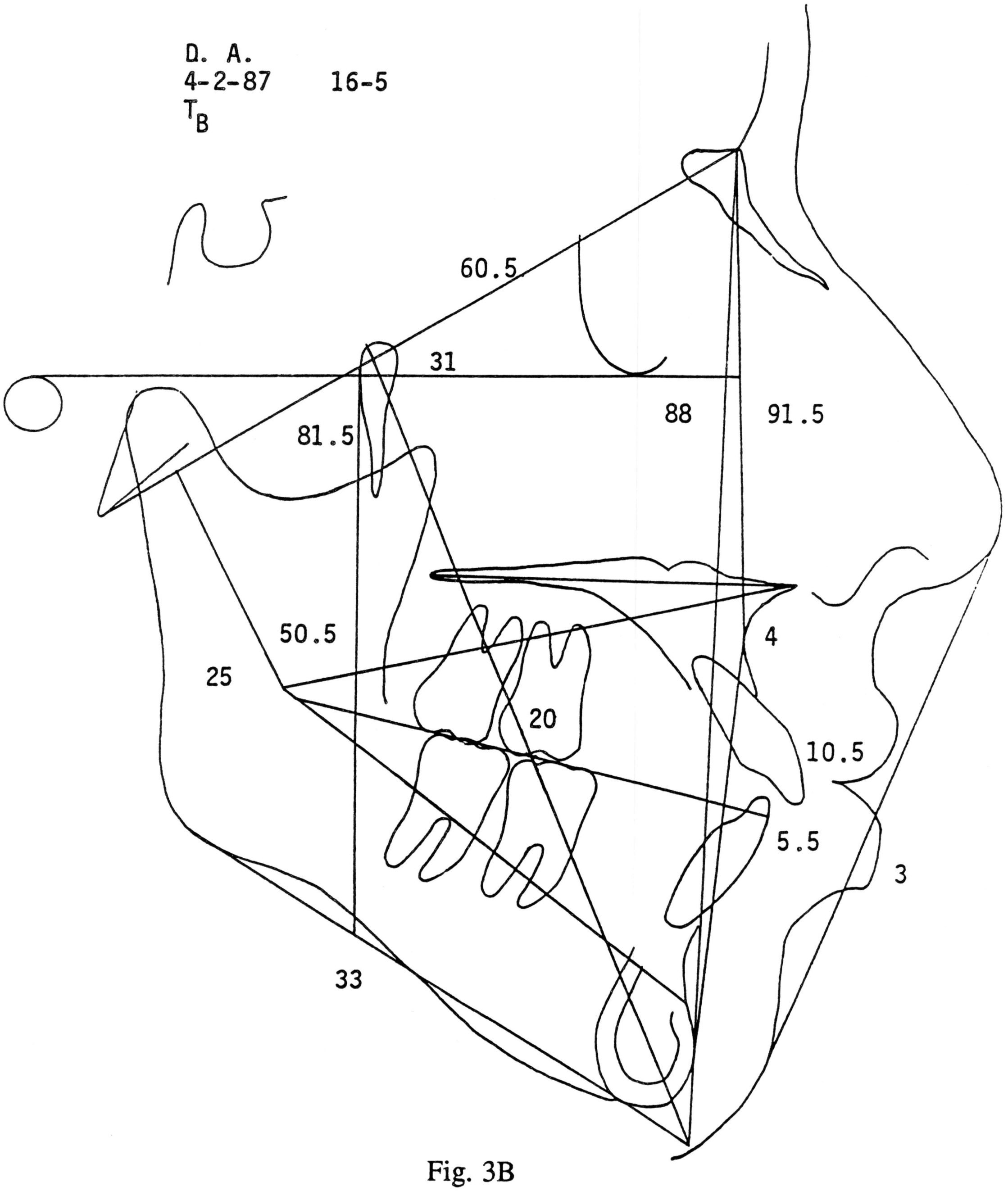


Fig. 3B

Cephalometric tracing (T_B) immediately following magnet removal.

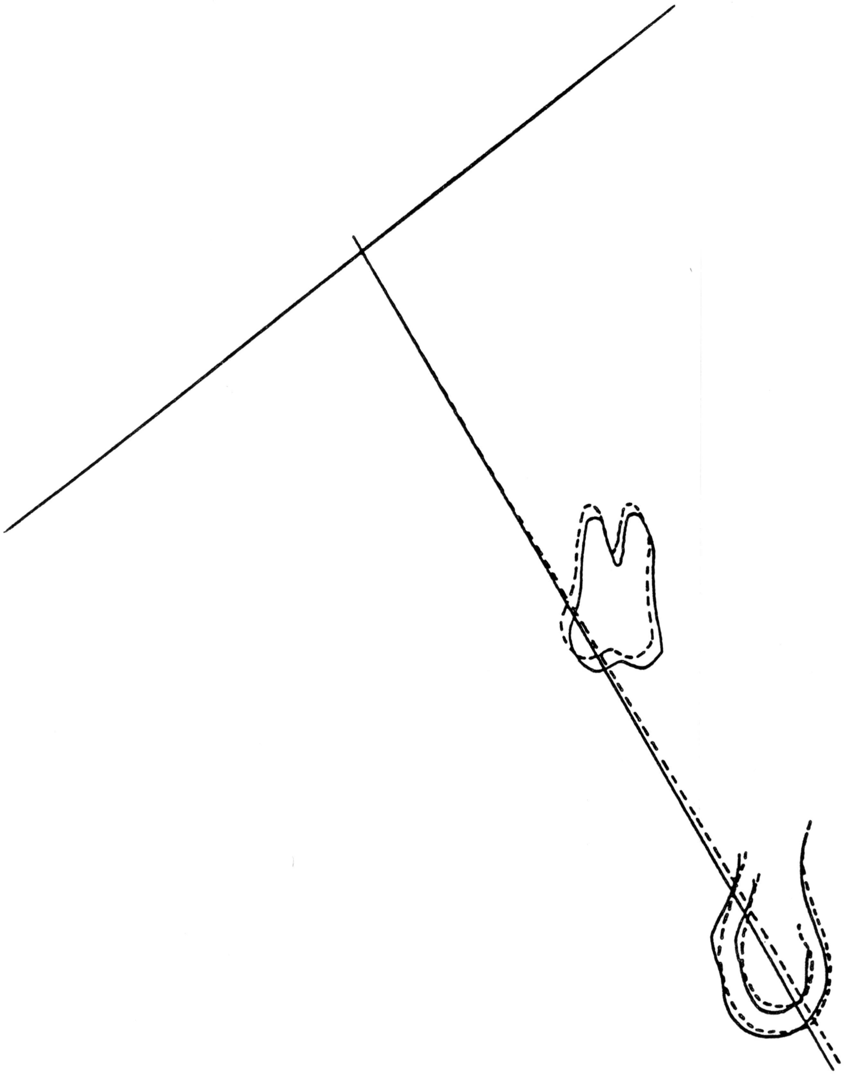


Fig. 3C

Cranial Base Superimposition along Ba-Na Plane at CC.
(T_A solid line; T_B dashed line).
Time interval between T_A and T_B for case #1 was 21 weeks.

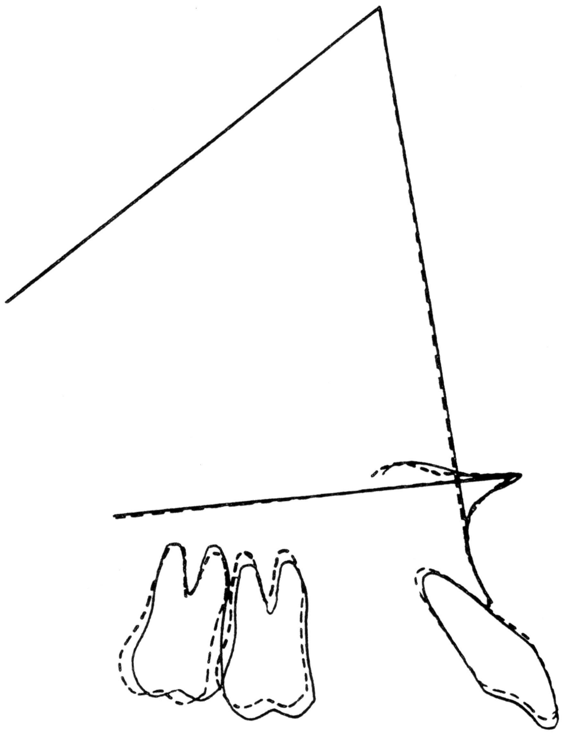


Fig. 3D Maxillary Displacement
Ba-Na Plane at Na.

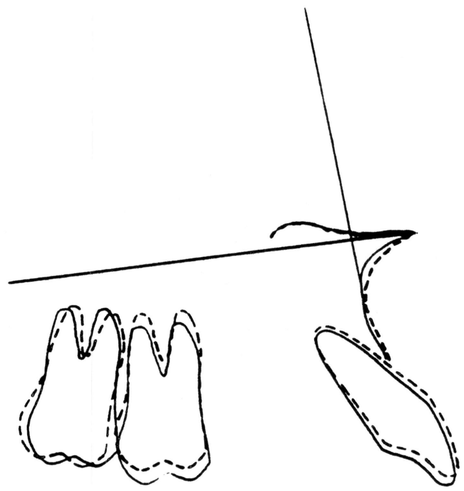


Fig. 3E Maxillary Superimposition
ANS-PNS at ANS.

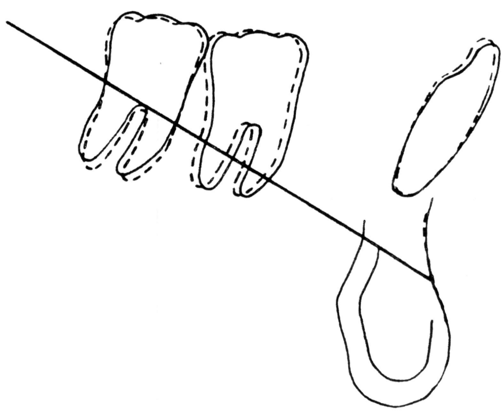
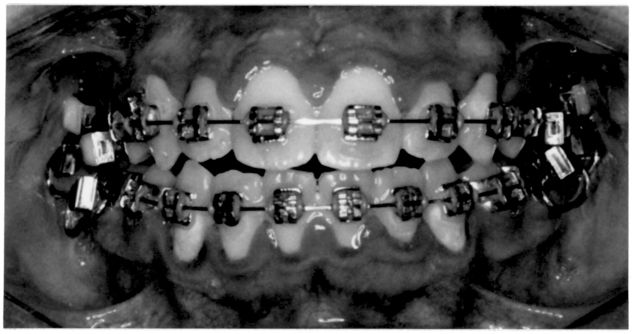


Fig. 3F Mandibular Superimposition
Corpus Axis at PM.



Photograph 5. The magnetic module on the lower left first molar is contacting the band so that correct alignment with its counterpart in the upper arch is not possible.

CASE #4 (A. M.)

SUMMARY DESCRIPTION

A. M. began orthodontic treatment in November 1983 to correct mandibular arch spacing and maxillary arch crowding where the cuspids were blocked out and the incisors were in lingual crossbite to the mandibular incisors. There was an anterior open bite tendency. The patient had a seizure disorder and she was under dilantin treatment. A quadhelix was cemented in the upper arch and a lower lip bumper was used to help correct the malocclusion. Interarch elastics were initiated one year later and continued with varied cooperation by the patient for another 1 $^1/_2$ years. A 2mm anterior open bite was recorded at this time.

At the time of magnet placement the cephalometric analysis revealed a dolichofacial pattern with a prognathic maxilla and protrusive dentition in both jaws. There was a class I malocclusion with a class II tendency. The patient showed moderate mentalis strain and a protrusive lower lip. Overjet was 0 mm and there was an open bite of 1.5 mm. The magnetic appliance to intrude the buccal sections for anterior bite closure was thus used.

TREATMENT PROCEDURE

Progress records were taken preceding magnet placement (Fig. 4A) on November 6, 1986. The magnetic bands were cemented a few days later. Instructions were given in the same manner as to the other patients with magnets. One month after magnet cementation the magnets on the right upper and lower second premolars had become malaligned and there had been movement of the upper premolar lingually. A light cross elastic was used to aid in the correction of the crossbite. There was poor cooperation with elastic wear and nine weeks after magnet placement a quadhelix appliance was constructed and cemented for expansion. The magnets were adjusted at each appointment and instructions on the correct care of the appliance given each time. Some breakage was noted at 18 weeks of magnetic wear, possibly associated with an epileptic seizure. The wire supporting the magnet to the lower left first molar was broken, and the magnet of the upper right first molar had broken loose from the band. The casing of the lower right first molar had also opened. The remaining magnets were adjusted until the magnets were removed after 21 weeks of placement. Records were taken immediately following magnet removal (Fig. 4B).

TREATMENT RESULTS

Cranial Base Superimposition (Fig. 4C). Superimposing along the basion-nasion plane at center of cranium revealed minimal change of the facial axis. The first molar was intruded slightly and also distalized.

Maxillary Displacement (Fig. 4D). Superimposing along the basion-nasion plane at nasion indicated a slight rotation of the palatal plane where PNS dropped down and ANS remained stationary.

Maxillary Superimposition (Fig. 4E). Superimposing on the ANS-PNS plane at ANS revealed intrusion of both first and second molars as well as slight torquing of the central incisor. The premolar did not intrude or extrude but seems to have shifted forward slightly.

Mandibular Superimposition (Fig. 4F). Superimposing on corpus axis at PM revealed slight extrusion of the molars while the premolar and the central remained essentially unchanged.

In summary, patient #4 showed no appreciable change in facial axis position. The upper molars showed some intrusion while the lower molars showed nearly the same amount of extrusion. This could be due in part to some tipping changes and a slightly different direction of the x-ray beam. From the models, 3 $^1/_2$ mm of expansion was measured at the upper first molars while the width between the lower first and second molars increased 1 mm for each. There was no appreciable change in the widths at the upper and lower second premolars. The maxillary second molars tipped distally and buccally.

A. M.
11-6-86 15-2
T_A

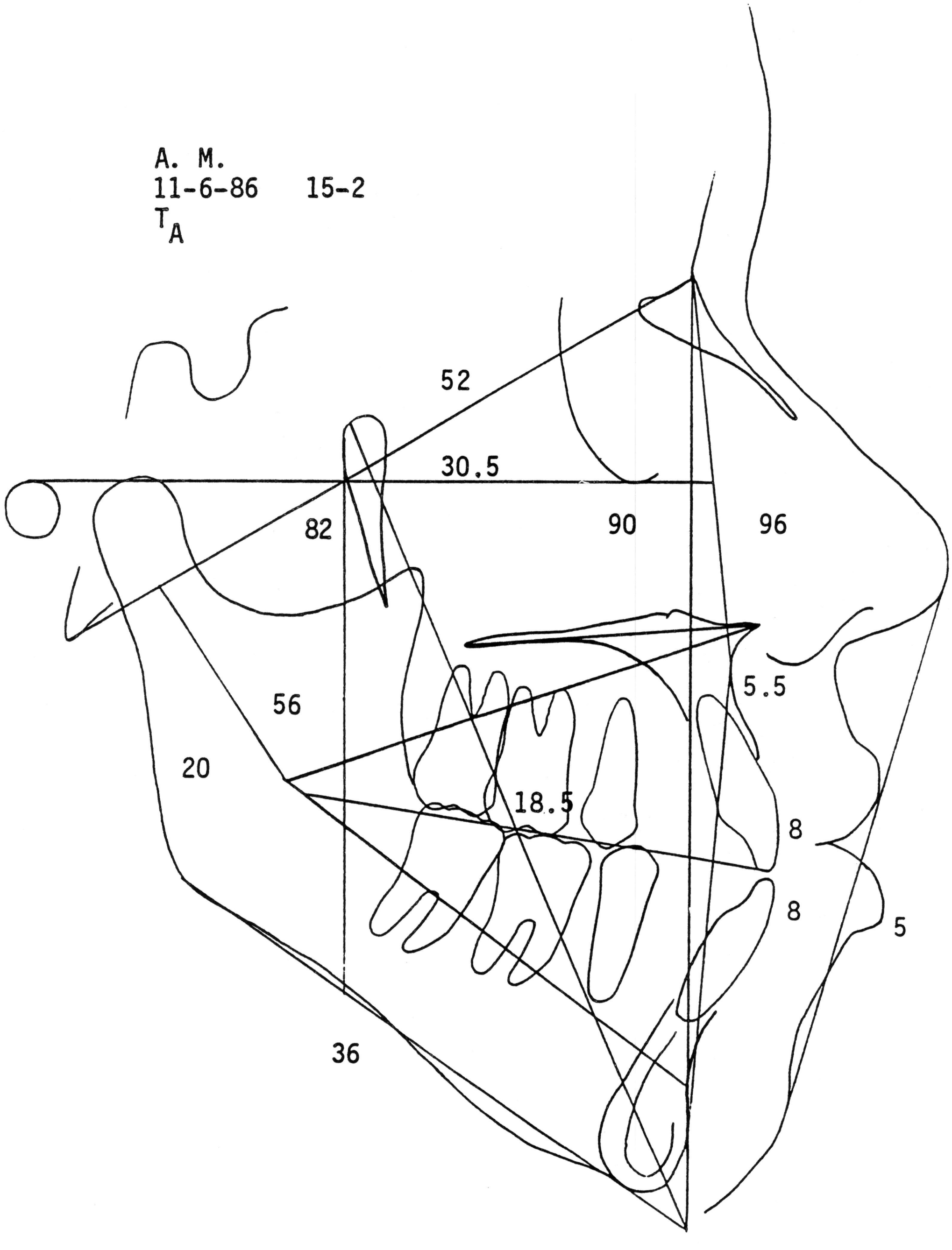


Fig. 4A

Cephalometric tracing (T_A) immediately before magnet placement.

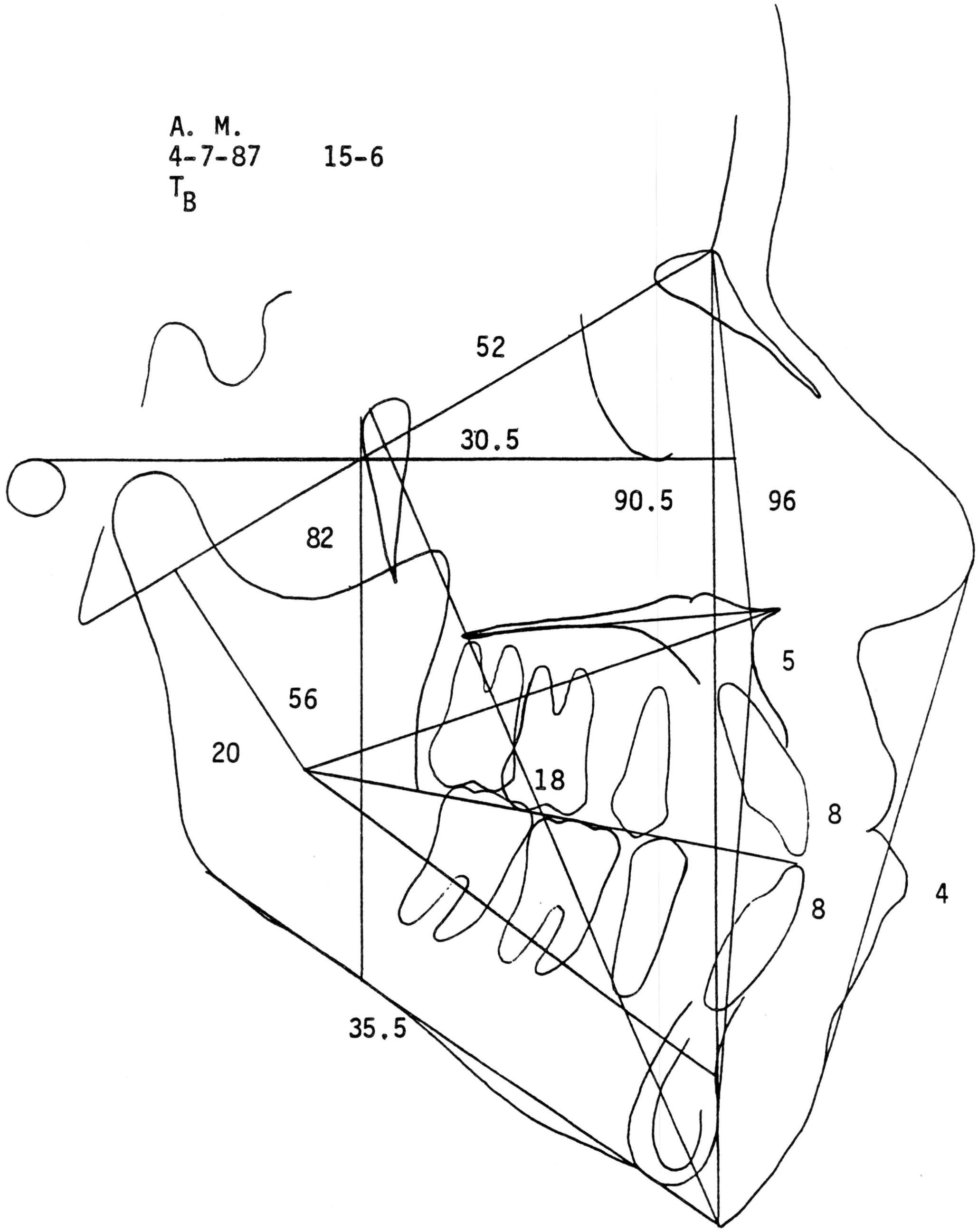


Fig. 4B

Cephalometric tracing (T_B) immediately following magnet removal.

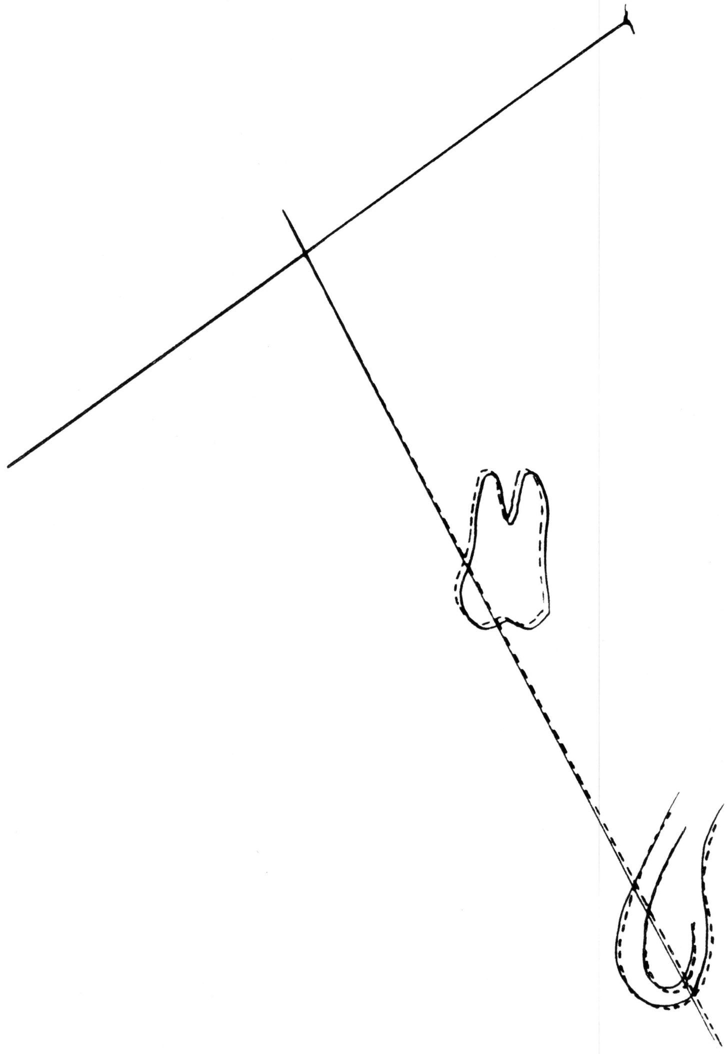


Fig. 4C

Cranial Base Superimposition along Ba-Na Plane at CC.
(T_A solid line; T_B dashed line).
Time interval between T_A and T_B for case #1 was 21 weeks.

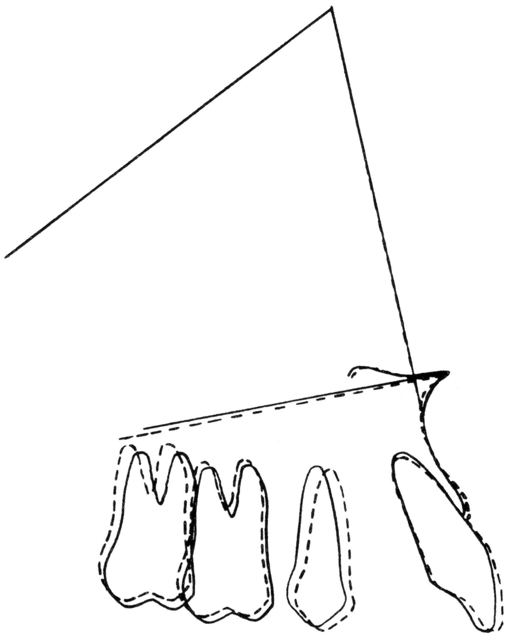


Fig. 4D Maxillary Displacement
Ba-Na Plane at Na.

Fig. 4E Maxillary Superimposition
ANS-PNS at ANS.

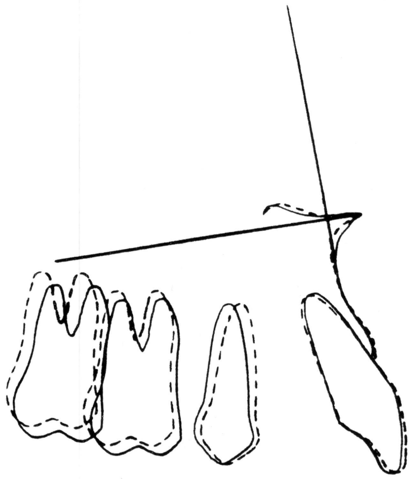
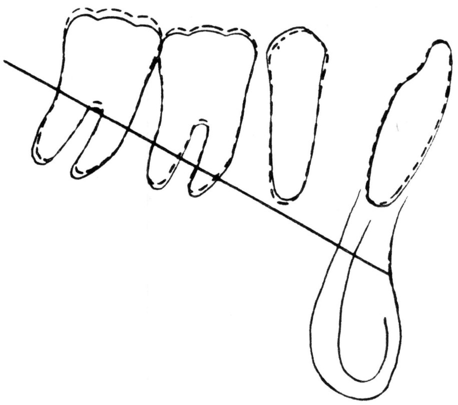


Fig. 4F Mandibular Superimposition
Corpus Axis at PM.



CASE #5 (L. F.)

SUMMARY DESCRIPTION

L. F. started orthodontic treatment in July 1983. Her initial cephalograms showed a Dolichofacial pattern with a class II div 1 subdivision right Angle classification. The maxilla and mandible were prognathic with protrusive upper and lower dentitions. The upper arch was constricted and there was a unilateral crossbite on the left. The anterior open bite was 3 mm and an overjet of 7 mm. A tooth size discrepancy was evident by upper peg laterals. Medical history showed heart murmur, anemia, and scoliosis. The patient had been diagnosed as having Marfans Syndrome. She had had two spinal fusions and a Harrington rod placed. Orthodontic treatment was started with a Haas appliance, and since then there has been very poor cooperation on the part of the patient. Surgery was recommended as an adjunt to orthodontic treatment several times but refused by the patient and the parent. Upper first premolars were extracted one year after treatment began. Spaces were closed with grey chain and there was some reduction of the anterior open bite. Buccal segment intrusion using magnetic forces was then attempted. Preceding magnetic placement cephalometric analysis (Fig. 5A) showed a dolichofacial pattern with a prognathic maxilla. The upper and lower dentitions were no longer protrusive, the upper arch had been expanded, and all spaces closed. The anterior open bite was 1.5 mm.

TREATMENT PROCEDURE

Bands were removed from all molars in October 1986 and impressions taken. Intrusion forces were needed on the maxillary first, second, and third molars as well as mandibular first and second molars. The maxillary third molars were in occlusion with the mandibular second molars because of the upper first premolar extractions. Medical Magnetics

Incorporated recommended that intrusion of the buccal segments be done in two phases due to the odd number of teeth and the absence of complete pairs. It was not recommended that magnets be placed on the lower second premolars against magnets on the upper first molars because of the root surface size difference, thus intrusion in two phases was planned. Magnetic appliances were constructed for maxillary third and second molars, and mandibular second and first molars. Photographs, x-rays, and impressions were taken immediately before placing magnets on November 20, 1986. The appliance was checked as much as possible since the patient kept her appointments sporadically. It was noted that there was little horizontal or vertical deflection of the magnets between appointments unlike the other patients that were being treated with similar appliances, as well as no crossbite production. The magnets on the third molars were very hard to adjust since they were placed so far posteriorly in the arch and the patient had a hard time opening her mouth very wide. Moderate tissue irritation from the mandibular magnets and the supporting wires was a problem (Photograph 6) and the patient used wax to reduce the tissue irritation in the vestibules. At 12 weeks of magnetic treatment, it was evident that the chin strap was not being worn. Also it was found that the patient had a habitual forward positioning of the mandible (she could attain centric on her own by being asked to bite right), so that the magnets were not approximated. It was explained to the patient that there were no results with the magnetic appliance because of the above mentioned reasons, and that an alternative mode of treatment had to be considered such as surgery. The patient mentioned that she wanted to give it another try but missed her subsequent appointments. The magnets were removed after 21 $^1/_2$ weeks of placement and records taken (Fig 5B). At this time it was noted that crossbites had developed in the third molar region and the patient confirmed that she had worn the chin strap more faithfully. The magnets were also deflected somewhat as noted on other patients.

TREATMENT RESULTS

Cranial Base Superimposition (Fig. 5C). Superimposing along the basion-nasion plane at center of cranium revealed no appreciable change in facial axis position.

Maxillary Displacement (Fig. 5D). Superimposing along the basion-nasion plane at nasion indicated no change in point A position or palatal plane. The third and first molars show slight intrusion while the second molar shows possible extrusion. Some distalization is seen in the posterior section. There was slight torquing of the central incisor.

Maxillary Superimposition (Fig. 5E). Superimposing on the ANS-PNS plane at ANS revealed the same as described for figure 5D.

Mandibular Superimposition (Fig. 5F). Superimposing on corpus axis at PM revealed some extrusion of both first and second molars as well as slight extrusion of the central incisor.

In summary, patient #5 showed no appreciable change with the magnetic appliance, partly due to the failure in cooperation and a habitual forward positioning of the mandible. It was interesting to note that, after reevaluation at 12 weeks of magnetic treatment and the patient's decision to wear her chin strap more often in order to avoid surgery, crossbites developed and there was some deflection of the magnets.

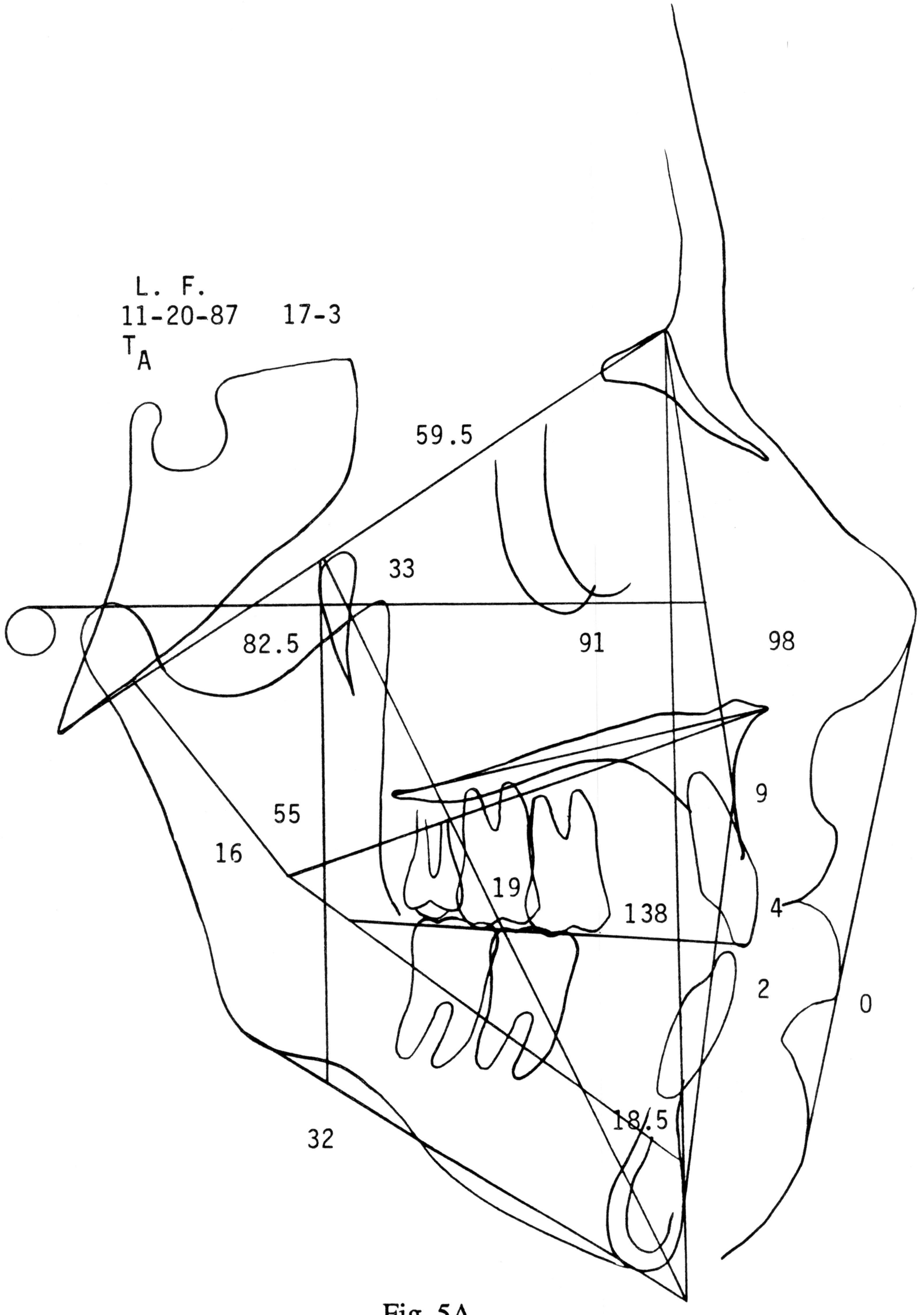


Fig. 5A

Cephalometric tracing (T_A) immediately before magnet placement.

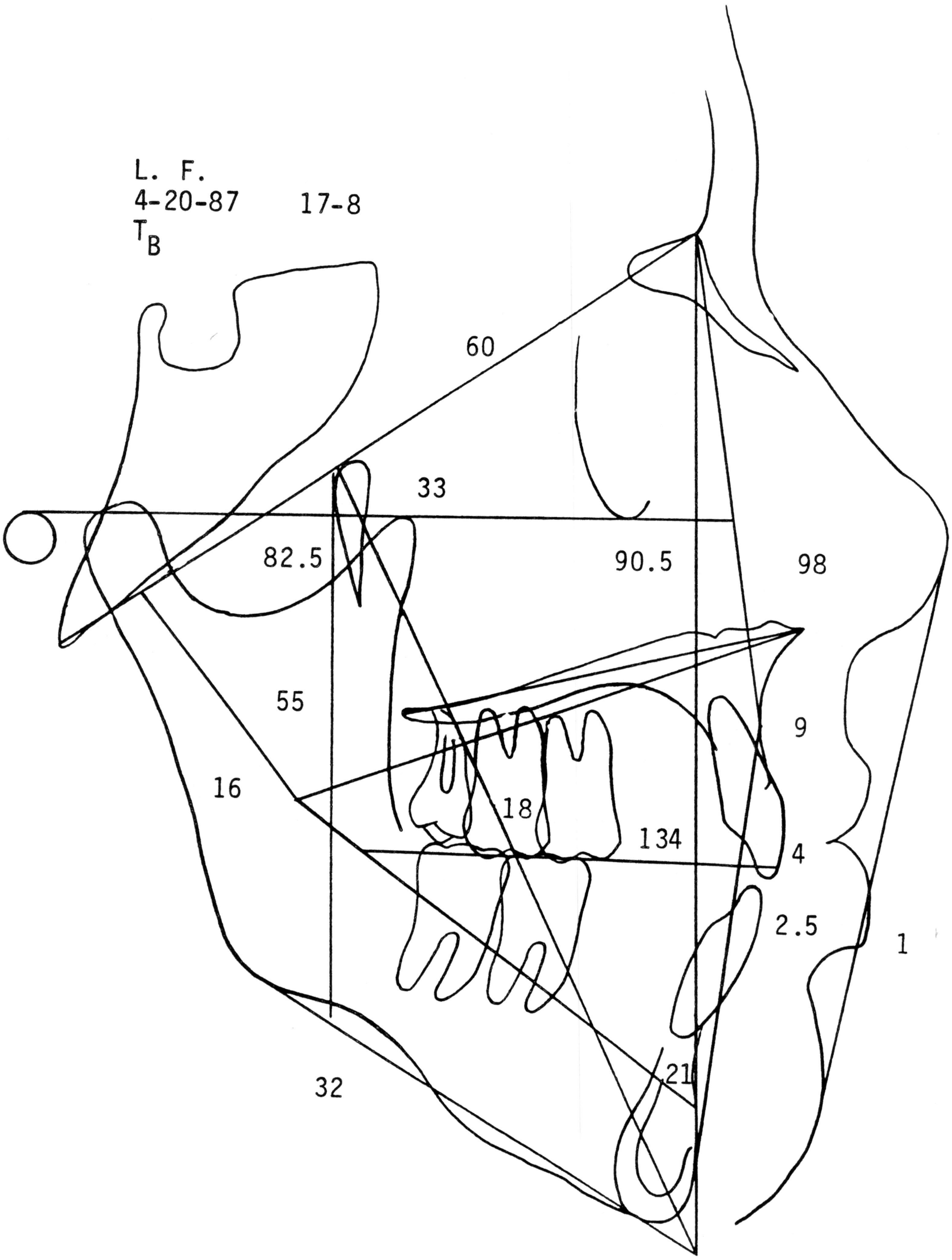


Fig. 5B

Cephalometric tracing (T_B) immediately following magnet removal.

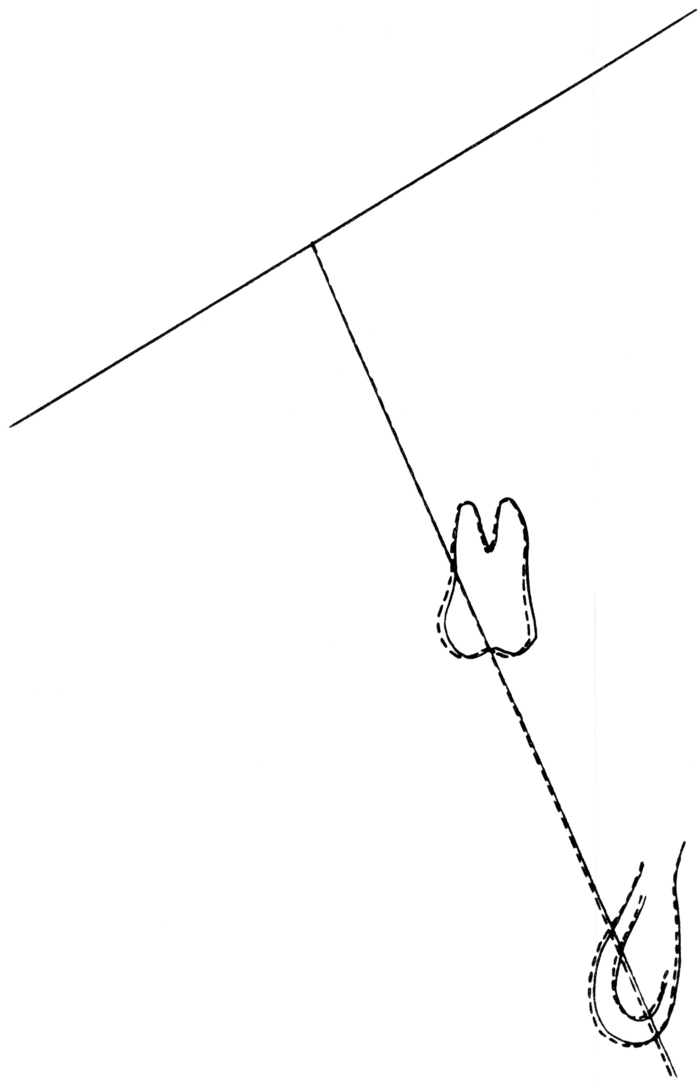


Fig. 1B

Cephalometric tracing (T_B) immediately following magnet removal.

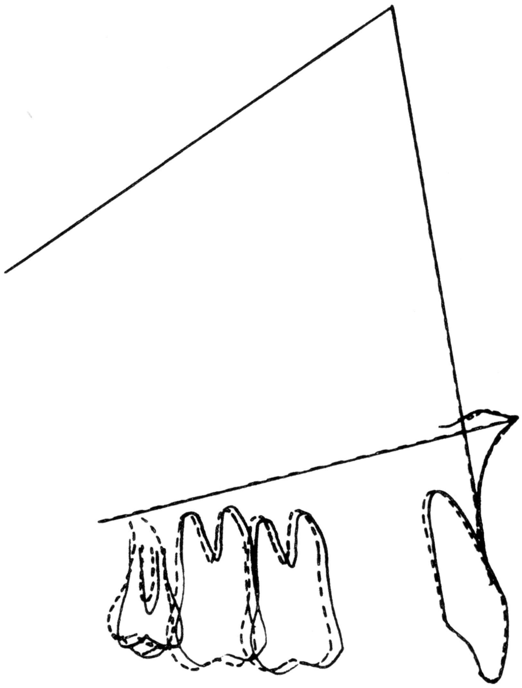


Fig. 5D Maxillary Displacement
Ba-Na Plane at Na.

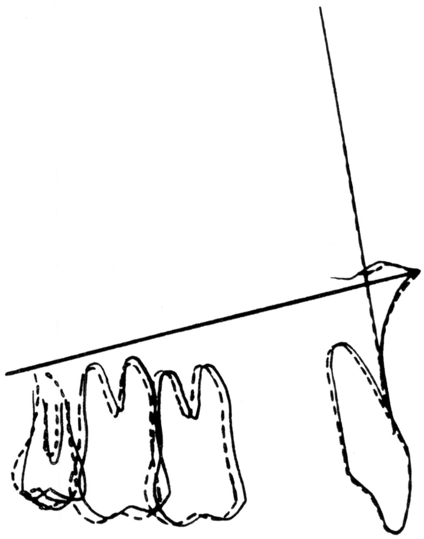


Fig. 5E Maxillary Superimposition
ANS-PNS at ANS.

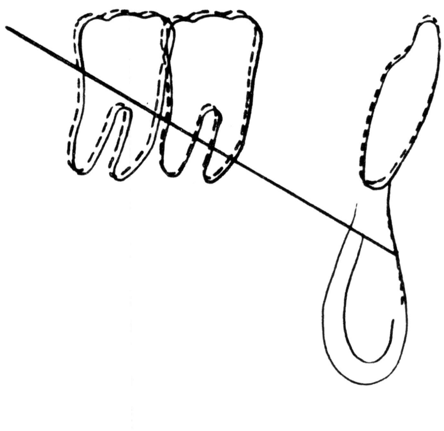
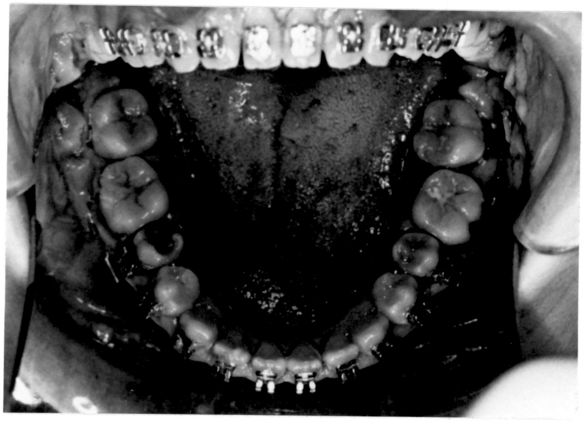


Fig. 5F Mandibular Superimposition
Corpus Axis at PM.



Photograph 6. Irritation in the right and left lower vestibules caused by the supporting wires and the magnetic modules of the lower arch.

Case #6 (C. B.)

Summary Description

C. B., a 12 year old female, was not treated orthodontically before placement of magnetic bands. The initial cephalometric tracing (Fig. 6A) reveals her to have a moderate dolichofacial pattern with a mild class II tendency. The maxillary dentition is severely protrusive with a strong tongue thrust, and an anterior open bite of 6 mm. There was occlusal contact only in the molar area.

Treatment Procedure

Magnetic bands were cemented on all first molars and second bicuspids on November 20, 1986. At the same time bonds were placed on the maxillary and mandibular centrals and laterals, and sectional wires placed for alignment. The patient was also instructed to avoid tongue thrust and it was noted that she was very conscious of this problem afterwards. During her appointments she held her tongue on the "spot" (on the palate just posterior to the incisive papilla) without being reminded to do so. One month later the upper second premolars had collapsed and were in lingual crossbite. The patient was instructed in wearing cross elastics to help correct the crossbite while the magnets on the molars were allowed to continue their intrusive force. Seven weeks after initial magnet placement, a quadhelix was constructed and cemented for expansion of the premolars. This quadhelix was connected to the premolars and not, as customarily done, to the molars. The appliance was activated for expansion. One month later, the quadhelix was removed for adjustment since the molars had expanded too much. Room was left for the molars to collapse again and they were tied to the quadhelix wire with grey chains. Crossbites were still a problem and it was difficult to approximate the magnets for maximum intrusion force. The magnets were removed after 21 1/2 weeks of treatment and records taken immediately following removal of the appliance (Fig. 6B).

TREATMENT RESULTS

Cranial Base Superimposition (Fig. 6C). Superimposing along the basion-nasion plane at center of cranium revealed no change in the facial axis and movement of the maxillary molar distally. Growth was apparent by the movement of the symphysis down the facial axis.

Maxillary Displacement (Fig. 6D). Superimposing along the basion-nasion plane at nasion revealed a reduction in point A and a downward growth of the palatal plane. The molars, premolars, and incisors were distally displaced.

Maxillary Superimposition (Fig. 6E). Superimposing on the ANS-PNS plane at ANS revealed intrusion of the molar as well as the premolar with slight change in torque of the incisors.

Mandibular Superimposition (Fig. 6F). Superimposing on corpus axis at PM revealed extrusion of both molar and premolars well as distalization. The incisor shows considerable uprighting.

In summary, the magnetic forces produced crossbite problems which were difficult to correct and this interferred with intrusion forces. There was a slight reduction in the anterior open bite mainly due to an upward bowing of the lower central incisors and improved tongue control. In measuring expansion on the models, a 4 mm expansion was found at the upper first and second premolars due to the quadhelix appliance. 1mm expansion was measured between the lower second premolars. There was no expansion or constriction measured at the upper or lower molars between beginning and ending models.

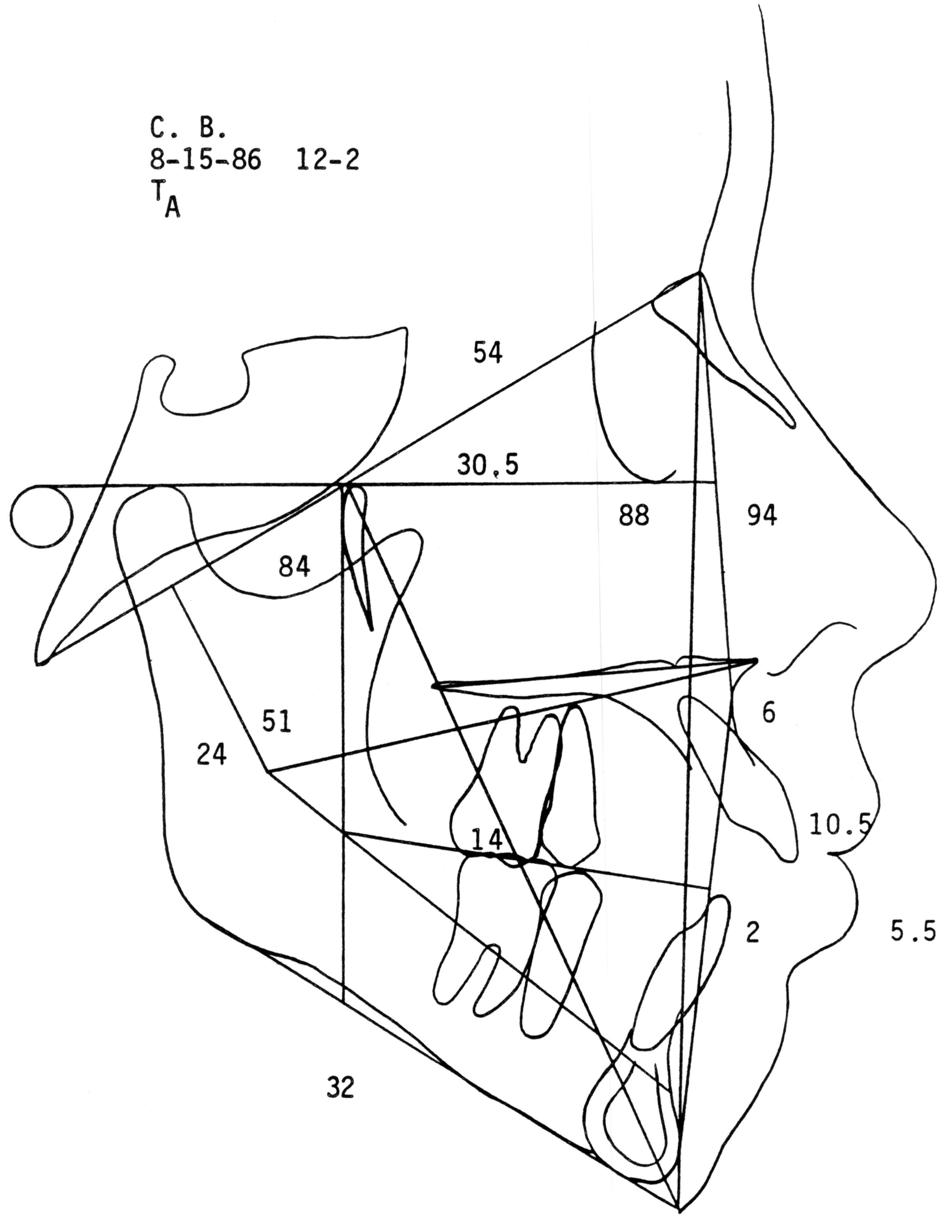


Fig. 6A

Cephalometric tracing (T_A) immediately before magnet placement.

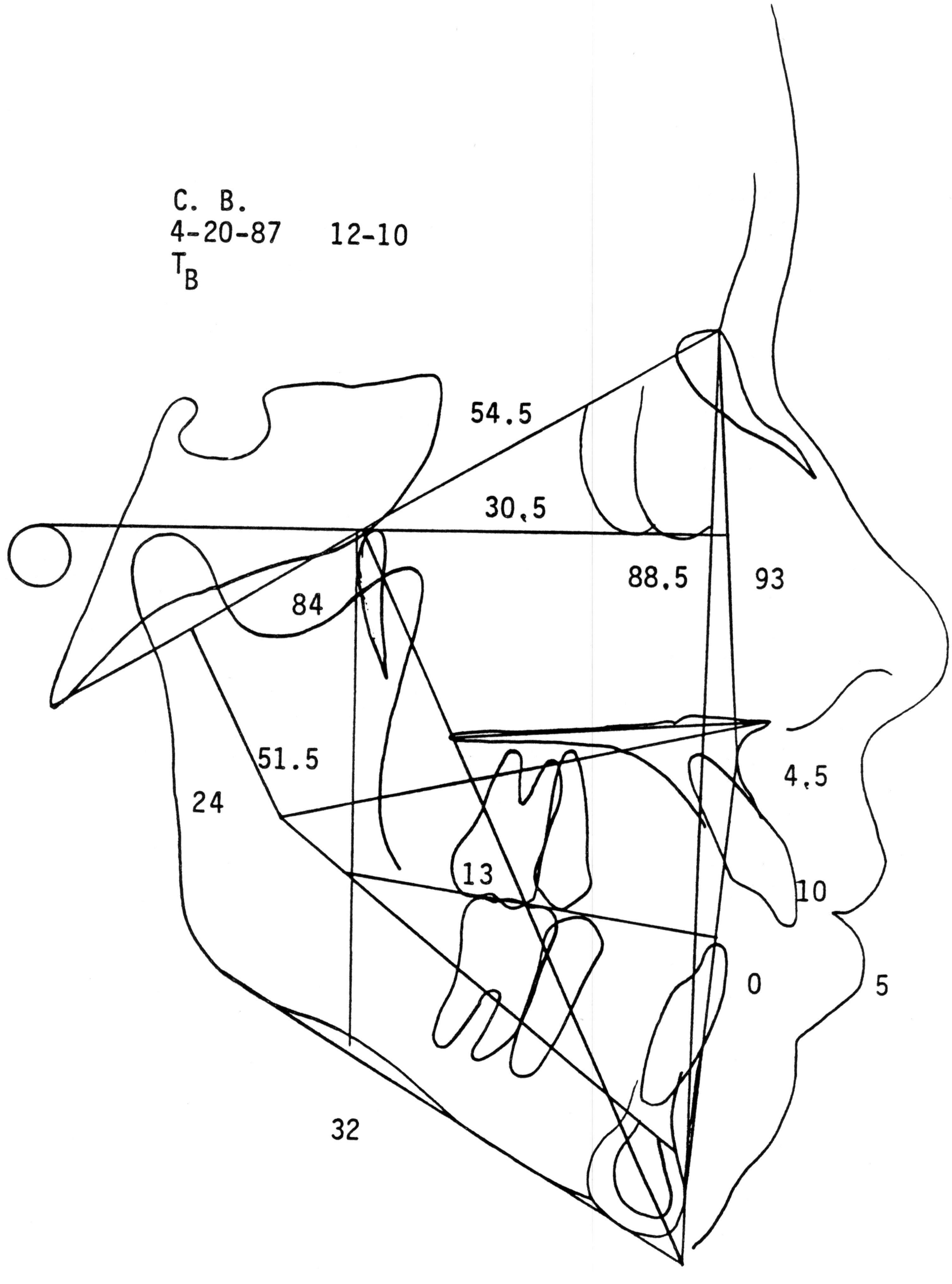


Fig. 6B

Cephalometric tracing (T_B) immediately following magnet removal.

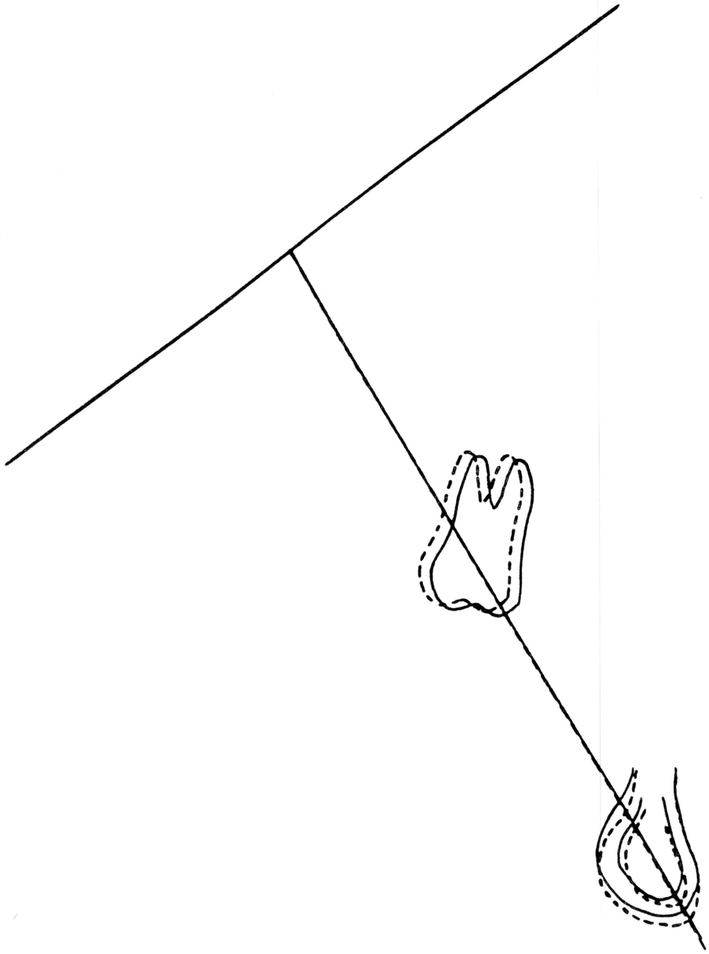


Fig. 6C

Cranial Base Superimposition along Ba-Na Plane at CC.
(T_A solid line; T_B dashed line).
Time interval between T_A and T_B for case #1 was 21 $^1/_2$ weeks.

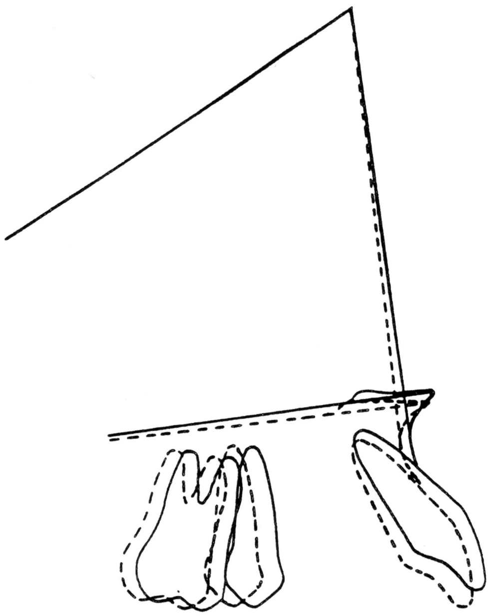


Fig. 6D Maxillary Displacement
Ba-Na Plane at Na.

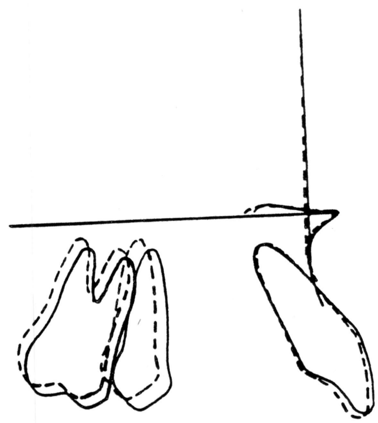


Fig. 6E Maxillary Superimposition
ANS-PNS at ANS.

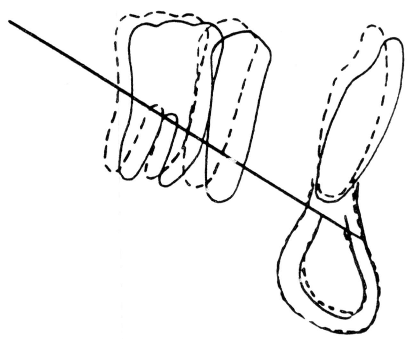


Fig. 6F Mandibular Superimposition
Corpus Axis at PM.

DISCUSSION

The results of the six cases reported in this study show some of the difficulties that can be encountered while using magnetic appliances for buccal section intrusion. After 21 weeks of magnetic appliance treatment there was no appreciable closing of the facial axis as well as no substantial reduction in the lower facial height as seen from the superimpositions of the beginning (T_A) and ending (T_B) cephalometric tracings. Also both slight intrusion and extrusion were evident on these superimpositions by the teeth that were banded with the magnetic appliances. This cephalometric effect of intrusion and extrusion could be attributed to the various directions of tipping (mostly buccally or lingually) seen by the teeth treated with magnets on all six patients in this study. When the magnets become even slightly malaligned, the vectors of the forces are redirected and pure intrusive forces are lost as exemplified by the diagrams in Figures A & B.

Magnets set in repulsion are quite unstable and try to push each other away in any direction possible. They are surrounded by complex force vectors that make them difficult to control as opposed to attracting magnets which have more predictable force vectors between them. This complex force system of magnets set in repulsion can explain the tipping results of those teeth treated with magnets and the posterior crossbite formation generally seen in all patients of this study.

In the cases reported in this study, one could see that there was some reduction of the anterior open bite. This was mostly due to sectional wire treatment mechanics in which the anterior teeth were allowed to move independently of the posterior teeth. Also, the supplementary treatment with interarch elastics to correct crossbites in the anterior sections contributed to the closing of the anterior open bite as seen in case #2.

It is well known that a tooth being moved orthodontically will move fastest if it is allowed to move along the path of least resistance. Therefore when placing the $SmCo_5$ magnets on the bands it was recommended to allow the teeth to intrude with no other forces acting upon them from archwires or other such appliances. The disadvantage in doing so is that most of the control is lost and one of the results is the production of crossbites. A possible reason for the experienced collapse of the upper arch and expansion of the lower arch that was seen in most of the cases presented in this paper, is a design problem. The magnets on the lower arch were supported by 0.036" wire so that there was an adjustment capability throughout treatment. The magnets on the upper arch were fixed (soldered) to the bands around the teeth and were not adjustable (Fig. C). Because of the supporting wires in the lower arch, the magnets were deflected buccally and gingivally during mastication. This changed the force vector in such a way that there was a force acting on the upper teeth in a superior and lingual direction, while the lower teeth experienced a force pushing them inferiorly and buccally. If such a situation is permitted to continue for any length of time then the maxillary arch will collapse and the mandibular arch will expand. The more the crossbite is created, the worse the situation becomes until a point is reached, where the magnets can no longer be adjusted for pure intrusion and other means of correcting the created crossbite must be used such as quadhelices in the upper arch and lingual arches with a constricting force in the lower arch. This, however, reduces the capability of intrusion since the teeth that are now being intruded "en block" are not allowed to move in the path of least resistance.

According to Medical Magnetics Incorporated, the force generated by close proximity of the magnets used in this study is in the order of 100 to 200 gms depending on the distance between the two magnets. The correlation is as follows:

If the distance between two opposing magnetic modules on one side is:	Then the approximate force exerted between those two teeth is:
Centric Contact	224.0 gms
0.5 mm	116.2 gms
1.0 mm	73.7 gms
1.5 mm	53.9 gms
2.0 mm	39.7 gms
2.5 mm	31.2 gms

From this table one can determine the importance of keeping the magnetic modules in closest proximity. It is necessary to check the patients who are wearing such an appliance very often to adjust the magnets for maximum force especially when intrusion of molars is attempted. In his book, Bioprogressive Therapy, Ricketts, *et all*[20], describes an optimal force of 100 to 150 gms/cm2 of enface root surface for tooth movement; thus for intrusion of posterior teeth, the following forces are suggested:

	Force of:	150 gms/cm^2	100 gms/cm^2
Lower first molar		130	85
Upper first molar		120	80
Lower second molar		110	75
Upper second molar		105	70
Upper and lower premolars		45	30

The forces generated by the magnets are in this range, especially when the magnetic modules are between 0.5 mm and 2.0 mm apart. Since the molars have a greater root surface area than the premolars, it is more important to keep the magnets in close proximity at the molars (0 to 1mm) for optimum force, while the distance of the magnets on the premolars can be allowed to have a greater separation.

In the cases presented in this report, intrusion was very slight. Results could have been improved by:

1. Controlling crossbite development from the beginning to avoid lost time when

it is impossible to align magnets correctly for intrusion forces.

2. Avoiding deflection of the magnets by increasing the strength of the wire supporting the magnets on the mandibular arch.

3. Increasing treatment time.

4. Remaining on a soft diet in order to avoid deflecting the magnets.

5. Keeping maxillary and mandibular teeth in contact most of the time by improving chin strap wear.

To avoid the creation of crossbites from the beginning one could suggest that a type of retainer be constructed that would keep the maxillary arch from collapsing and still give the teeth the opportunity of intruding through the path of least resistance. A similar device should be constructed for the lower arch to avoid expansion. A lingual arch could be used in this case, although it must be realized that there could be less intrusion of the mandibular teeth as a result.

Another way to control iatrogenic crossbite formation might be to place the adjustable magnets on the upper arch and fixed magnets on the lower arch. This would give the tendency of expansion of the upper arch and constriction of the lower arch (against the tongue). In those cases where it is necessary to expand the maxillary arch, such a design would be advantageous. Once there would be enough expansion of the upper arch, then more expansion should be avoided by placing palatal bars between the molars and premolars as necessary. In order to avoid removing the magnetic bands to construct such a device, one might place lingual attachments on the bands prior to band cementation for removable palatal bars. In this way, expansion can be monitored by placing or removing the lingual appliances. In order to keep the lower arch from constricting, it would be feasible to construct a type of retainer that the patient would wear so that individual tooth intrusion could still be possible.

One could imagine that the deflection problem of the mandibular support wires could also be improved by making the wire even stiffer. This would reduce the adjustment capabilities during treatment and increase the possibility of dislodging the cemented band while adjusting the possition of the magnet. By increasing the stiffness of the wire it would also be necessary to take an exact bite registration before the construction of the magnetic appliance due to the decreased capability of adjusting the magnets at the time of cementation.

Still another idea to increase the efficiency of buccal section intrusion with magnetic forces is to intrude the entire section "en block." This could be achieved by using sectional wires tied to tubes or brackets in addition to the magnets. These attachments could be placed on the buccal surface in order to be able to place lingual attachments as well, for the removable palatal bars mentioned earlier.

Not all patients are suited for posterior intrusion with magnetic forces. Patient #5 was a weak and frail individual with debilitated masticatory musculature. It was noted that she habitually postured her mandible forward to avoid the magnetic forces. Thus it may be suggested that this type of individual may not be suited for treatment with interarch magnetic forces such as used in this study.

One of the limitations of this study, was the concomitant treatment with interarch elastics to help correct crossbites that developed during magnetic treatment and the subsequent use of expansion and/or constriction appliances such as upper quadhelices and lower lingual arches when it was noticed that there was no improvement with elastic wear (poor cooperation). A suggestion for improving the design of this study is to control crossbite development from the start of magnetic treatment so that there are no extraneous factors involved in the results. Another limitation was the difficulty in recording a true centric bite in all the records attained to show the same degree of anterior open bite. It was found that the degree of the anterior open bite varied between the types of records taken. One suggestion would be to use a centric registration for all initial, progress, and final records as they are taken. This would ensure consistent results when viewing photographs, models, or cephalograms at each one of the times presented (initial, final, etc.).

In conclusion, it is felt that there is definite room in the field of orthodontics for magnetic forces since the author has shown that magnetic forces are great enough for tooth movement. Nevertheless, in order to successfully use magnetic forces in an interarch arrangement such as shown in this study, the technique for intrusion of posterior teeth must be improved in conjunction with further clinical trials to enhance the possibility of attaining the required objectives.

There is a real need for such an appliance as discussed in this paper since many of our problem cases are those that have a vertical pattern with an anterior open bite and choose not to be corrected surgically. For these patients the ideal treatment is to intrude the posterior segments and to improve their facial esthetics by reducing the lower facial height and rotating the facial axis anteriorly. If we can improve the results of intrusion with the magnets, then such an appliance would be part of our treatment suggestions and we, as orthodontists, could help some of those patients who have problems similiar to those mentioned in this report.

SUMMARY AND CONCLUSIONS

Six dolichofacial patients were treated with magnetic forces to intrude the buccal segments in an attempt to reduce the lower facial height and close the facial axis in order to reduce a preexisting anterior open bite.

The following conclusions were drawn:

1) After 21 weeks of magnetic wear, there was no appreciable closing of the facial axis or reduction of the lower facial height.
2) The cephalometric tracings showed both intrusion and extrusion of the teeth that had magnets attached to them.
3) Closing of the anterior open bite was mostly due to movement of the anterior sections independent of the magnetic forces.
4) Pure intrusive forces were difficult to attain so that all patients experienced crossbite development either buccally or lingually.
5) Magnetic forces were strong enough to produce tooth movement.
6) Technique changes are necessary in order to improve control over tooth movement and achieve the desired intrusion of the posterior teeth.
7) Patient cooperation is necessary in order to get the needed magnetic forces to intrude teeth.
8) Magnets such as the ones used in this study are not ideal for all patients. Previous diagnosis is necessary in order to improve result possibilities.
9) Repelling magnets have more complex force vectors and thus are more difficult to control than attracting magnets.

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